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STUDIES OF THE NEEDHAM, MASS., DISTRIBUTION SYSTEM

BY ROGER G. OAKMAN*

[*Read September 22, 1944.*]

In many of our New England towns that have had a public water supply system for the past fifty years or so, the original systems were laid out and designed with one large pipe line running from the pumping station, through the center of the town to a reservoir or standpipe. The sizes of the mains tapered off rapidly as extensions to side streets were made. In later years, as new houses were built and it became necessary to make further extensions of these mains, pipe of the same size as that originally laid in the street was extended to meet the demands for new services.

Often the size of these pipe lines depended upon: (1) the number of houses that wanted the water service; (2) the stock of pipe on hand; (3) the amount of money available in the budget for extensions; (4) the ability of applicants to pay the guarantee requested; and (5) the idea that one more house could be served from a 100-ft. extension of the present 4-in. or 6-in. main.

Too often we find that these 100-ft extensions just grew over a period of years to lines of 4-in. and 6-in. pipe 1,000 to 4,000 ft. in length.

Few small cities and towns have made follow-up studies of their distribution systems after the original design, and altogether too much emphasis has been placed on the idea that a high static pressure constitutes a good water supply, very little thought being given to actual flow pressures. In the outlying sections of towns, fires were generally few and small. Hence they did not require the use of large quantities of water to put them out, and water departments did not

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fully realize the inadequacy of their distribution systems until they experienced a bad fire.

Many of us cannot understand or take the time to work out the capacity of mains by the Hardy Cross method of analysis, as the mathematical work involved would overwhelm us. One practical way for a superintendent to learn what is the capacity of his distribution system is to go out and make fire flow tests of the system. From the results obtained, fire flows can be easily computed on the basis of residual pressures of 20 psi remaining in the mains or down to 10 psi residual pressures as recommended in the report of the Committee on Painting of Hydrants. According to this report, hydrants shall be classified as A, B, C, and the tops and caps painted with the following colors to indicate their capacities:

Class A. Hydrants. Green tops and caps for hydrants with flows of 1000 gpm with a residual pressure of 10 psi.

Class B Hydrants. Orange tops and caps for hydrants with flows of 500 gpm with a residual pressure of 10 psi.

Class C Hydrants. Red tops and caps for hydrants with insufficent capacity to supply pumps with 500 gpm with a residual pressure of 10 psi.

With this thought in mind, the writer with the assistance of the New England Insurance Exchange made a series of fire flow tests to cover the town of Needham. Observations were taken at 70 points throughout the distribution system. The following procedure was used in making the flow tests: (1) the static pressure was read at the hydrant; (2) one 2½-in. hydrant cap was removed and the hydrant opened to secure a full stream; (3) the residual pressure on the main was recorded; (4) the flow at the hydrant was taken by means of a Pitot tube, the gauge being held in the center of the stream of water about 1½ in. from the outlet to obtain the maximum reading*; and (5) the inside diameter of the nozzle was recorded.

Referring to a table showing the discharge from various sizes of hydrant outlets, using a coefficient of 0.90, the flow of water from the particular hydrant being tested can be determined. If just one gauge is used to record the pressure flows, a correction must be made to determine the correct residual pressure by adding the friction loss

*This pressure could also be taken from a pressure gauge attached to the other nozzle cap; both readings should give practically the same results.

in the hydrant branch and barrel to the nozzle top pressure. The flow from a particular hydrant can then be figured for residual pressures of 20 psi or 10 psi at the main with the use of a hydraulic slide rule or by using the following proportions which are accurate enough for practical purposes:

$$\frac{\text{(Pressure Drop 1)}}{\text{(Pressure Drop 2)}} = \frac{\text{(Flow 1)}^2}{\text{(Flow 2)}^2}$$

The results of the fire flow tests at Needham were tabulated as shown in the following sample schedule:

Street	Station	Residual	Hydrant Flow	Discharge (gpm) at Residual Pressure of 60 psi	20 psi	Required Flow (gpm)
(1) Great Plain & Chapel	75	59	2100	2040	4000	2500
(28) Highland, West	66	39	2340	1040	3100	3000
(27) West, Fairview	95	40	770	600	920	1500
(44) Mayflower, Great Plain	83	5	246	120	220	1000
(46) Brookline, Town Line	100	3	170	110	150	1000

We determined the flow at selected points throughout the distribution system and, after recalculating them to get the discharge at 20 psi of residual pressure, the results were tabulated and compared with the required flows, as set up by the New England Insurance Exchange.

Fire flow requirements were chosen at the values suggested by the National Board of Fire Underwriters for flows in Residential Districts. The required fire flow depends upon the character and congestion of the buildings as follows: 500 gpm for small buildings of low height, with 1/3 of the lots built upon; 1000 gpm for larger and higher buildings; 1500 to 3000 gpm for closely built districts of high value residences; and up to 6000 gpm for densely built sections of three-story buildings.

Needham's required flows were set at 1000 gpm for residential districts and up to 2500 and 3000 gpm for the more densely settled and manufacturing districts. So far as the business section and high value districts were concerned, the fire flows were ample and exceeded the requirements set by the Board.

We were amazed at the poor flows that were recorded for some of the lines in the outskirts of the town. I presume that years ago two fire streams of approximately 500 gpm were considered ample for these outlying sections. But many houses have been added since then, and some extensions have been made that overload the existing system; also, over a period of years, the inside of the pipe has been slowly building up incrustrations and tubercles which have cut down flows considerably.

The sections that are deficient have been plotted on a map, and studies are being made to correct these deficiencies as soon as possible. We started this program back in 1940, but due to the war it was curtailed. We expect to pick up and continue this work as a post war project.

In making these studies it is well to bear in mind the following recommendations of the National Board of Fire Underwriters taken from their Standard Schedule for Grading Cities and Towns: "In connection with the supply mains, arteries and secondary feeders shall extend throughout the system. These feeders shall be of sufficient size, considering their length and the character of the sections served, to deliver fire flow necessary for the district, shall be frequently spaced (about every 3,000 feet) and looped. . . . Six-inch to be considered the minimum size satisfactory for hydrant supply in residential districts; to be closely gridironed with 6-inch cross-connecting mains at intervals not exceeding 600 feet, or where initial pressures are high a satisfactory gridiron may be obtained by a liberal per cent of larger mains cross-connecting the 6-inch at greater intervals; in new construction 8-inch should be used where dead-ends and poor gridironing are likely to exist for some time, and 6-inch only where blocks are 600 feet or less in length. In high value districts the minimum size to be 8-inch with cross-connecting mains at distances as given above; 12-inch and larger mains to be on all principal streets and for all long lines not cross-connected at frequent intervals."

We must keep in mind the different carrying capacities of the different sizes of pipe. For instance: (1) a 14-in. pipe has 1.5 times the capacity of a 12-in. pipe, 2.4 times that of a 10-in., 4.3 times that of an 8-in., and 9.3 times that of a 6-in.; (2) a 12-in. pipe has 1.6 times the capacity of a 10-in. pipe, 2.9 times that of an 8-in., and 6.2 times that of a 6-in.; (3) a 10-in. pipe has 1.8 times the capacity of an 8-in. pipe, and 3.8 times that of a 6-in.; and (4) an 8-in. pipe has 2.1 times the capacity of a 6-in. pipe.

Another very important rule for us to keep in mind is that low velocities for fire flows are desirable because of the accompanying low pressure losses. Maximum pressure losses for pipe lines should not go much beyond 5 psi per 1000 ft. of pipe to secure best results.

A table for the loss in pressure in pounds per square inch for 1000 ft. of pipe gives a clear picture of the losses in various sizes of pipes:

	Loss in psi for Stated Diameter of Pipe in inches					
Flow - gpm	4	6	8	10	12	14
250	29	4	1	—	—	—
500	104	14	3.5	1.3	0.5	0.25
1000	—	50	13	4	1.7	1
2000	—	—	50	15	6	3

From a study of this table, one can readily understand why 4-in. pipe is outlawed for use in the distribution system, and why 6-in. pipes should be used in short lengths and then only when it is properly tied in to form a good gridironing of the system.

The results of our tests have presented a big problem for us in some sections of our town, and I realize that we cannot relay all of our pipes to get the desired results. We are, therefore, handling our problem by: (1) studying the trend of new growth with the possibility of laying pipe lines large enough in the new developments to tie in and reinforce the weak spots in our distribution system; (2) looping dead end pipe lines to form a gridiron; (3) cleaning existing pipe lines to give immediate increase of fire flows; (4) giving consideration to cleaning and relining some of our larger pipe lines; (5) relaying some mains with larger sized pipes in some places; and

(6) setting aside each year a definite amount of money to enable us to carry out this replacement program.

In closing, I wish to thank Professor George E. Russell of the Massachusetts Institute of Technology and Mr. George Booth of the National Board of Fire Underwriters for their assistance and information.

Discussion

Horace L. Clark (Sanford, Me.). I have followed more or less the same scheme in Sanford. A survey was made by the National Board of Fire Underwriters about 1933 and again about 1940. We based our extensions of mains on the results that we obtained. Our second survey showed gratifying results. The first survey had showed some weak points. We reinforced them and met with a great deal of success in improving fire flows. In looking for trouble we came on unexpected things. We put a blowoff on a street that our records showed had a 4-in. line in it. When we opened the blowoff, we received complaints from the customers. We dug the main up and found that somebody had attached the 4-in. line to a main line through a five-eighths inch gooseneck. The result was quite obvious.

Sidney S. Anthony (Augusta, Me.). Recently we cut a piece out of a 6-inch line that was laid in 1929. It was very badly encrusted. Most of the pipe that we laid between 1929 and 1932 seems to have had a poor coating on it. The trouble, however, was not all in the coating but also in the metal. Some pipe that has been in service since 1906 is just as shiny as the day it was laid. If we investigate some of our low pressures, we may find that some of the pipe that was laid around 1930 is worse than much older pipe.

Donald C. Calderwood (Nashua, N. H.). Fire flow tests will also show closed gate valves or broken gate valves in the system. It is impossible to see what is going on in the ground, and the only true picture of conditions is obtained by actual fire flow tests.

Sidney S. Anthony. A few years ago we found a 12-inch feeder which was supposed to supply the biggest part of the town in which one disc of the valve controlling this main had broken off and dropped down.

WILLIAM W. BRUSH (New York, N. Y.). I don't know whether there is a single man here who is in charge of a water system and who is now laying pipe that is not protected either by a satisfactory cement lining or a satisfactory coaltar lining. If he is laying pipe that is not satisfactorily protected, I think he is definitely doing a disservice to his community. He does not know whether the supply which is being furnished and which may not be a very active water will not at some time in the future become an active water as a result of otherwise desirable treatment.

ROGER OAKMAN. Making fire flow tests is not nearly as difficult as it sounds, and it does not stir up the water as much as the ordinary man thinks. When we started making our tests I worried considerably about possible complaints of rusty water and stopped meters, but I was happy to find that we did not have more than one or two complaints throughout the system. One is bound to open up a leak or a weakness in the system, but that is a pretty good thing to find out when the system is not required to meet the demands of a bad fire.

Fire-flow tests every five or ten years furnish excellent checks on what is happening to the system.

DAVID E. MOULTON (Portland, Me.). There is another aspect of these flow tests that has not been mentioned. I don't know how many of our water companies have the problem of allocating equitably the cost of water to more than one community. The Portland Water District has sixteen different sets of rates, or sixteen different communities to which it serves water. I made quite a long study at one time trying to arrive at what I felt was the most equitable way to apportion the cost to the different communities. I studied the assessed valuation, the population, the cost of the distribution mains and services in the system, the total amount of water used, and the total amount paid in rates. I finally became convinced that the most equitable way was to find the demand that was made on the system and to prorate the sizes or the number of hydrants. But when you compare a hydrant on a 16-inch main with one out on the end of a 6-inch main and attempt to charge the country town on the basis that that hydrant is worth as much as the larger one, it did not seem equitable. Hence we made flow tests and put the capacity on every

hydrant in the Portland Water District. The matter never became a rate case, but I was preparing the information for such a contingency.

HAROLD W. GRISWOLD. I might make the point that these distribution studies offer an excellent opportunity to make a beginning on postwar planning. I do not agree that these studies should be deferred to the postwar period. They should be done now, so that with the coming of 1945 there will be a backlog in every water system of work that should be done—worthwhile work, not made work in any sense.

We were very much surprised in Hartford, in beginning a study perhaps a year ago, to find that we had a quarter of a million dollars worth of work that ought to be done at once, and probably a million dollars worth of work that was worthwhile and overdue. I think that every one of you will find, if the system he operates is over twenty-five years old, that there will be weak spots. Those can be disclosed by hydrant flow tests, by mathematical analysis, by Pitometer methods, or by a combination of the three.

BAYARD F. SNOW (Washington, D. C.). The capacity of pipes, unless they are lined, decreases during their years of service. You start out with a pipe that may have three or four times the capacity that you need, but in a few years the curves of capacity and need cross each other and a point is reached where more water is wanted than at the beginning, and there is actually far less capacity. The desirability of lining the pipes, therefore, is unquestionable in the eyes of every practical man. To the question discussed by Mr. Oakman there is also a different approach, namely, hydraulic analysis. But where pipes are hooked up by goosenecks, contain closed gates, or have a pipe swab left in them, theoretical studies do not always work out well.

HURRICANES WITH SPECIAL EMPHASIS ON THE NEW ENGLAND HURRICANES OF 1938 AND 1944

BY LYNDON T. RODGERS*

[*Read November 16, 1944.*]

The people of New England have developed a great interest in weather since there is a large variety of weather in New England and since the occupations of so many people are such as to be greatly affected by the weather. The cold waves, heavy rains, deep snows, and high winds that affect this area are caused by storms that pass through or near this region. There are two types of storms: extra-tropical storms and tropical storms. Extra-tropical storms are the result of the development of a wave or disturbance on a cold front. These move through New England throughout the year averaging 1 to 3 storms each week. Tropical storms in full development are hurricanes that originate in the tropics and move into higher latitudes causing widespread destruction. The tropical storms that move through North America develop in the region of the doldrums in the south portion of the North Atlantic. Many begin near the Cape Verde Islands, others in the Caribbean Sea or the Gulf of Mexico. Likewise, hurricanes or typhoons develop near the Philippines, the Bay of Bengal and the Indian Ocean.

The Atlantic Hurricanes occur in the months of June to November, about 80 percent of them occurring in August, September, and October. Their frequency is quite variable ranging from as few as two in a year to as many as twenty-three with an average of about seven. The first indication of a developing storm is an increased shower and thunderstorm activity in the northeasterlies at the edge of the doldrum region. As the disturbance develops it moves westward quite slowly traveling at a velocity of 8 to 15 mph. The westward journey usually continues for six to eight days, and it is during this time that the disturbance grows into a hurricane with wind velocities that many times exceed 120 mph.

*U. S. Weather Bureau, Boston, Mass.

Storms that follow the normal path eventually curve northward and northeastward. At the time of curving, the storm usually slows up, but once it has begun to travel north or northeastward, it accelerates many times to velocities of 40 to 50 mph. It is at this time that the New England forecaster must be on the alert and get his warnings out if they are to be of maximum value to the people of New England. The hurricanes that cause high winds in New England are the ones that curve somewhere near the Bahamas and move northward along the Atlantic Coast passing near Cape Hatteras. Any storm that actually passes inland over any of the South or Middle Atlantic Coast States will lose much of its energy due to friction of the wind blowing over the land. Then we get little more than heavy rain, even though the storm does move into this area.

A large part of the damage done by hurricanes is caused by tides. Seventy-five percent of all deaths which occur in hurricanes are caused by drowning when sea water is swept in over low-lying land. High tides are caused by the strong winds which set up huge waves. The height of the tide depends upon the strength of the wind and the time it has been blowing from any one direction, and upon the characteristics of the sea shore. Long shallow inlets exposed to the sea or low-level beaches, with much shallow water near by, are favorable spots for flooding. Tides caused by hurricanes may often rise fifteen to twenty-five feet above normal tide levels. The place of the highest tide is just to the right of the hurricane path as it approaches the sea coast since on that side the wind has been stronger and blowing for the longest time from one direction. The tides are also higher if the path of the storm traces a line normal to the coast line. The waves caused by a hurricane move at a speed of about 30 mph, while the hurricane moves at a velocity of only 10 to 15 mph; so the swells reach the coast well ahead of the storm. These facts have been used to big advantage in predicting the path of a hurricane as it moves through the Gulf.

Very low barometric pressure is always found at the center of the hurricanes. Pressures of 27 and 28 inches occur frequently, and a low reading of 26.35 inches was recorded on September 2, 1935, on Lower Matecumbe Key, Florida.

Rainfall caused by hurricanes varies greatly in amount, ranging from less than one inch to as much as one hundred inches. A rainfall of 23.11 in. occurred in Taylor, Texas, in twenty-four hours. A hurricane in Jamaica caused 96 inches of rain at Silver Hill.

The hurricanes that are most famous in New England history occurred in 1816, 1821, 1938, and 1944. These four storms were very similar in development, path, and speed of movement. The amount of information available on the storms of 1816 and 1821 is limited, but we do have considerable information on the recent hurricanes.

The hurricane of 1944 was first reported as a disturbance on September 8 at 16 degrees north latitude and 60 degrees west longitude. In the next two days, this storm grew into an intense hurricane. Army bombers that went out at regular intervals and took observations of this storm gave accurate reports of the location and intensity of the storm. The hurricane moved northwestward at about 10 mph, and on September 12 a bomber pilot estimated the wind speed at about 140 mph. On the evening of September 13, it had reached a point about 300 miles east of Jacksonville, Fla. It was at 7 p.m. on this evening that the Boston Forecast Center sent out its first hurricane alert to all radio stations with a request for its broadcast. On the next morning, the Boston Office ordered the display of hurricane warnings and gave the following statement to all radio stations with a request for their broadcast: "Hoist hurricane warnings 9 a.m. Block Island to Portland and southeast storm warnings Portland to Eastport. Winds will increase along the Connecticut, Rhode Island, and southeastern Massachusetts coasts late today and over the remainder of the New England coast tonight reaching up to 80 mph Block Island to Portland and up to 60 mph North of Portland late tonight and Friday morning. These warnings are in connection with the hurricane now only a short distance off Cape Hatteras and moving northward. Full and complete precautions should be taken against destructive winds and extremely high tides in southern New England tonight and in southern and northern New England late tonight and Friday. Broadcast requested."

The hurricane moved northward at an accelerated rate of about

40 mph reaching the south coast of New England near the Connecticut-Rhode Island boundary at about 10:30 p.m. Up until this point, this storm had moved very much as the hurricane of 1938, but from here on the path was very different. While the storm of 1938 continued northward and curved toward Burlington, Vt., this one curved northeastward and passed into the Bay of Fundy. This change in direction made a big difference in the amount of damage to New England. The 1944 storm was just as intense as the 1938 storm, but since it curved northeastward, it did not spend so much time over this section and did not affect so large a portion of New England. Cape Cod was the only region to feel the highest winds and suffered greater damage in this storm than in 1938. The highest winds reported in New England in the 1944 hurricane reached a velocity of 82 mph at Block Island. However, unofficial reports from Cape Cod were as high as 95 mph. The highest sustained velocity for a 5-minute period in 1938 was 87 mph at Providence, R. I.

The storm of 1938 cost 499 lives and about $300,000,000 in damage. The storm of 1944 cost 390 lives, of which 344 occurred at sea, and about $100,000,000 in damage.

EFFECT OF THE HURRICANE OF 1944 ON MASSACHUSETTS WATER SUPPLIES

BY FRANCIS H. KINGSBURY*

[*Read November 16, 1944.*]

Weather Bureau reports available to the Massachusetts Department of Public Health on the morning of September 14, 1944, indicated the possibility of a hurricane reaching New England by that evening. Accordingly, the district sanitary engineers of the Department were directed to stand by at their offices throughout the day, to fuel all cars, and to check any equipment and supplies that might be needed, more especially equipment and supplies used in the disinfection of water.

As a result of a meeting of the Governor's Disaster Relief Commission held that morning, the Department was advised at 12:30 pm, through the office of the Adjutant General, that the hurricane was expected to reach New England by midnight and that the Governor directed all Department heads to stand by until the emergency was over.

The system of water supply coördination, organized in 1941 under the State Emergency Plan by Lt. Colonel Arthur D. Weston, Chief Sanitary Engineer and State Water Supply Coördinator, was then set in motion. Water supply officials throughout the state were notified of the probable hurricane and directed to fill all stand pipes and to take such other precautions as they deemed necessary.

The Department was kept informed of the progress of the hurricane and its effects by the office of the Adjutant General, through which all state police reports were available. Figure 1 shows the path of the storm center of the hurricane of 1944 and that of 1938. A map of the hurricane damage was plotted throughout the night from State Police reports and by 6:00 a.m. on the morning of September 15, 1944, a fairly accurate picture of conditions was available as shown in Figure 2.

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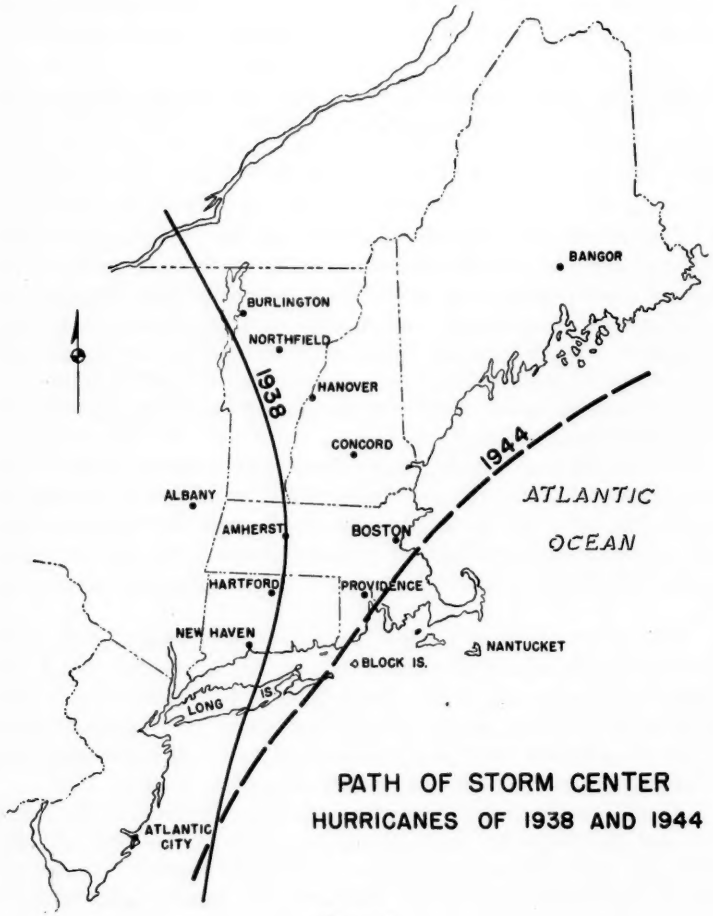

FIGURE 1

At 8:00 a.m. the district sanitary engineers in each district were given reports then available as to the various water supplies in their districts and were instructed to investigate and offer assistance.

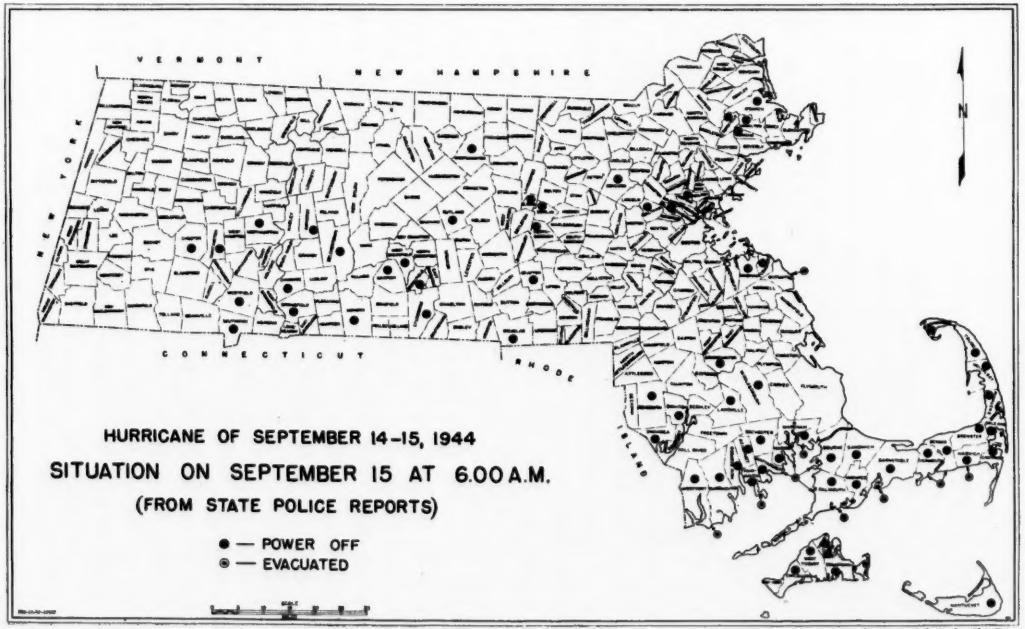
VERMONT
NEW HAMPSHIRE
NEW YORK
CONNECTICUT
RHODE
N
HURRICANE OF SEPTEMBER 14-15, 1944
SITUATION ON SEPTEMBER 15 AT 6.00 A.M.
(FROM STATE POLICE REPORTS)
● — POWER OFF
◉ — EVACUATED

FIGURE 2

Reports from southeastern Massachusetts indicated that Cape Cod and Buzzards Bay had been most seriously affected by the storm, and additional engineers were dispatched to this section from the Boston office.

At 11:15 p.m. on September 15, 1944, reports had been received at departmental headquarters from all district sanitary engineers, and from Martha's Vineyard, Nantucket, and Provincetown by State Police radio indicating that all public water supplies were in operation and that no source of public water supply had been affected by flood waters, although in two instances there was damage to water mains. In all instances where pumping machinery was dependent upon electrical power only, such power had been restored. In the Cape Cod and Buzzards Bay areas, all water supplies had auxiliary motive power for pumping water or regular Diesel engines. The installations of auxiliary power units at many pumping stations was due in part at least to the recommendations of the Department following the hurricane of 1938.

The importance of interconnections between municipalities was illustrated where water mains were broken at Fairhaven and Hyannis. At Fairhaven, water was being obtained for a section of the town from Acushnet which is supplied with water from New Bedford. The break at Hyannis occurred in the main from Hyannis to Hyannisport, and Hyannisport was supplied through a connection with the Centerville-Osterville Water District until the main could be repaired and disinfected.

At Tisbury, on Martha's Vineyard, the dike near the source of water supply for the town was overtopped several inches by salt water from Tashmoo Pond, but this did not result in pollution of the water supply.

Some of the semi-public water supplies in the village of Sagamore in Bourne were without power for pumping water, but water was supplied to residents by means of Army water trucks from Camp Edwards which were filled from the public water supply of the Buzzards Bay Water District.

The hurricane wave was not as devastating in this storm as during the hurricane of 1938. Figure 3 shows the tide curves at Buzzards Bay in the hurricanes of 1944 and 1938.

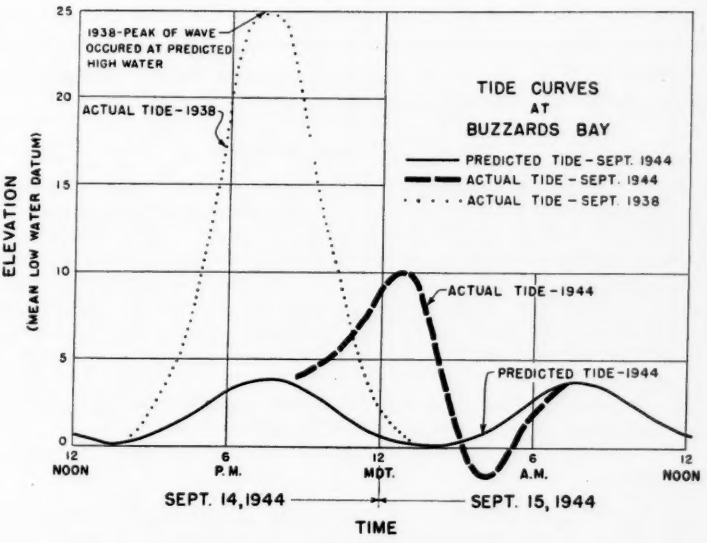

FIGURE 3

The district sanitary engineers contacted all local boards of health in Southeastern Massachusetts to offer assistance to private water supplies or health hazards resulting from flooded buildings. In this connection, mimeographed copies of instructions for the disinfection of drinking water and instructions for the disinfection of inundated basements, etc., were given to the local health officials for distribution.

The Department offered to assist local boards of health upon request relative to private water supply and analyzing samples of water from inundated wells. A total of 82 private sources of water supply was examined at the request of local boards of health; of these 46 were found to contain chlorides in such amounts as to make the water unsuitable for most domestic purposes, and 29 of the remainder were found to contain water with large numbers of coliform organisms. The latter wells were disinfected and pumped out and rechecked as to chloride content. In connection with this work,

a procedure was developed to determine in the field the chloride content or salinity of the water in the wells. The test, which was developed by A. R. G. Booth, Chief, Water and Sewage Laboratories, Massachusetts Department of Public Health, is as follows:

Field Test for Salinity

Use a clean glass-stoppered bottle of about 8-oz. capacity. Pour 50 ml. of the sample into the bottle and add 1 ml. of a potassium chromate indicator solution (50 gm. per liter). Add the entire contents of one of the amber glass ampules which contain 2½ ml. of silver nitrate solution (48.9 gm. per liter). Shake vigorously for half a minute. If at the end of that time and *while still shaking* the solution appears anywhere from *faintly reddish* to *brick red* in color, the chloride content is *less* than 500 ppm. If the solution remains *lemon yellow* in color the content is *greater* than 500 ppm and the water would be unpalatable because of the salty taste.

1. Avoid spilling the contents of the brown ampule on the hands as it will cause dark brown stains on the skin which are difficult to remove.
2. Wash the bottle in which the titration is carried out soon after titration is completed.

The recent hurricane emphasizes that storms of this nature may be expected in New England from time to time and emphasizes the importance of auxiliary units for pumping water. Also important is the matter of further interconnections between municipalities.

Acknowledgment is made to the staff of the Division of Sanitary Engineering, Massachusetts Department of Public Health for assistance in preparing this paper.

EFFECT OF THE HURRICANE OF 1944 ON RHODE ISLAND WATER SUPPLIES

BY WALTER J. SHEA*

[*Read November 16, 1944.*]

The hurricane of September 14, 1944, caused far less damage Rhode Island property than did the hurricane of 1938. The combination of high tide and high wind that characterized the hurricane of 1938 was absent in the later storm. Consequently damage caused by flood waters was relatively small. The loss of electric power was not widespread, and every water utility in the state had power from one source or another within a few hours of the end of the storm. Only two water supplies in the state were affected seriously enough by the storm to be worth mentioning in this paper.

The Bristol County supply was forced to shut down. This left consumers of three towns without water for two days. The source of this supply consists of four impounding reservoirs, three of which supply water to the fourth or intake reservoir. Water from the intake reservoir is pumped to the purification plant and after treatment into the distribution system. Under normal conditions, a low dam prevents sea water in the tidal portion of the Kickamuit River from mixing with the fresh water in the intake reservoir. The high water which accompanied the storm, however, caused sea water to overflow the dam. While electric power to operate pumping equipment was restored after a brief interruption, it would have pumped water of high salt content into the system. It was decided not to do this (1) because the water could not be used for drinking; (2) because it would exert adverse effects on boilers and other uses; and (3) because it would take some time to free the system of salt water when fresh water again became available. Instead, work was started by a contractor to install a wooden flume 750 ft. long to connect a pipe which empties water from one of the tributary reservoirs (known as Shad Factory Reservoir) into the upper end of the intake reservoir

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(called Kickamuit Reservoir) directly with the pumping station intake and thus bypass the salted reservoir. The flume was completed in about 36 hours by having the work go on for 24 hours a day. In this way, water service was restored in 48 hours. During the shut down the elevated storage tanks were cut off to conserve their contents for fire protection purposes. When filtered water was turned into the mains again, a heavy dose of chlorine was applied to provide a safeguard against contamination that might have found its way into the partially emptied piping system either through back siphonage or through leaks in the system. The additional precaution was taken of warning users to boil all drinking water drawn from the system during a period of 36 hours after service was restored. In the meantime, residual chlorine tests showed that chlorine had become well distributed throughout the system. In passing, a word should be said in praise of the conscientious manner in which the manager of the water company, Mr. Streit, and the Chief Engineer, Mr. Lafleur, worked day and night with little or no rest until the system was restored to use.

The other system in the state which was upset somewhat by the hurricane was the Newport system. Loss of power at the Lawtons Valley plant made it necessary to use an auxiliary source consisting of gasoline engines which had been installed for this purpose. The plant was run on these engines for three days, before the ordinary source of power was restored. Power was lost at the main pumping station in Newport for a period of about 12 hours; service was maintained without resorting to the use of the steam pumps.

Nonquit Pond, one of the sources of water for the city of Newport, became salted by sea water flooding a low dam which separates this pond from the sea, the resulting mixture contained from 1200 to 1500 ppm of chlorides. While the salt content of the pond was reduced somewhat after the storm, a good deal of rainfall will be needed to return this pond to a normal condition.

As the result of experience gained in Rhode Island from the two recent hurricanes, it becomes obvious that certain minimum requirements must be met by waterworks systems to maintain uninterrupted service following hurricanes:

1. Every waterworks pumping station should be so equipped

that there will be no interruption in power of long enough duration to deplete finished water storage below a safe limit.

2. Water pumping stations and treatment plants located near the sea, or near waterways where flooding may occur, require special provisions for emergencies. A source of raw water beyond the reach of flooding sea water is essential. At the time of the hurricane of 1938, the lack of such a source at one plant prevented the use of auxiliary steam pumps which could have made up for the lack of power from the normal source. This lack of enough fresh water even for boiler use occurred when broken mains drained the storage tanks and sea water contaminated the intake reservoir.

In closing, it seems worth while to point out that from Rhode Island experience operators of a system who fail to be ready for a hurricane emergency may be put to great expense in adopting temporary expedients, subjected to the strongest kind of criticism from the consuming public, and finally forced to install the facilities that would have avoided interruption of service if they had been installed beforehand.

THE PLACE OF PUBLIC WORKS CONSTRUCTION IN POST-WAR PLANNING

BY WILLARD F. ROCKWELL*

[*Read January 11, 1945.*]

In this great country of ours, it is the precious privilege of all political parties to present preposterous preëlection promises of prosperity, and after victory or defeat, to leave their procurement to posterity.

Everyone will agree that taxes can have a drastic effect on business, but few will agree that politicians of any party have found any method of improving the condition of citizens by state socialism or by government planning of all enterprise. There are certain definite functions of government, and these are properly divided into federal, state, county, and local community functions. Such necessary government operations and functions usually require the construction of buildings and public works, which should be planned far in advance of needs, with the definite object of improving the welfare of all the citizens. Public works projects should be planned when private business is good and executed when private business is bad. The work should definitely be planned to take up the slack of business depressions, not only because it fits the people's needs, but also because it permits such work to be done at far lower costs than prevail during times of good business, which is also for the permanent benefit of the public. Bonds can be sold with very low rates of interest if the public works are of a definite utilitarian value and so planned as to guarantee their future usefulness to the community.

A few years ago, we had 30 million workers producing 65 billion dollars per annum, and some economists believe we should have in the post-war period 60 million workers producing 140 billion dollars in goods and services. Admittedly, a strong dose of inflation can make 65 billions look like 140 billions, but it will not add 30 million workers to pay rolls. Most economists seem to agree that private enterprise cannot furnish so many jobs for years to come. Some economists doubt even that we want more than two out of every five people on the pay rolls, since young people require time to be educated and

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old people must be retired for various reasons before their life span has passed.

Government work has always had a place in our economy, and its planning offers one of the greatest possibilities for preventing unemployment and maintaining progress in our industrial advancement. This nation has the highest standard of living in the world and in three years has produced the greatest fighting power in history, because we are the most advanced industrial nation in the world. It is industry that has mechanized our farms and homes and enabled us to produce more with less physical effort, and, in some cases, with less mental effort, so that we have more time and more brains to devote to further mechanization. In such countries as India and China, where less than one per cent of the people are engaged in industry, we find the lowest standards of living and the least ability to oppose foreign oppressors.

One of our first Federal ventures in business was the Post Office Department. While its operations are generally considered satisfactory, and are conceded as a necessary Federal function, it furnishes examples of the complaints against Federal operation and control. Wages are low, the work is hard, and opportunities for advancement are very limited. There has been no increase in basic wages in 20 years. The higher positions are not filled from the ranks, but are reserved for political rewards, without regard to merit. Because the post office is essentially a monopoly, there is no check on the efficiency of its operations or its relative cost. It is, however, typical of government enterprises in which the three greatest handicaps are: (1) failure to provide sufficient incentive to the workers and active management; (2) inability to determine proper costs and efficiency of operation; and (3) constant danger that whichever political party is in power will exploit the political possibilities rather than improve the service.

In the recent elections, a number of propositions to permit further acquisition of properties for operation by federal, state, or local governments were defeated; and there seems to be a strong public reaction against government ownership and control. Furthermore, both major political parties emphasized their belief in the competitive, free enterprise system. However, any public reaction against

state control should not be permitted to limit or hamper government in the exercise of necessary functions.

One of the first of these functions prescribed in our history is the protection of the health of the people. The United States Public Health Service was established in 1798, and its duties include:

1. Prevention of interstate spread of diseases and suppression of epidemics.
2. Coöperation with state and local health boards.
3. Investigation of diseases of mankind.
4. Supervision and control of biologic products.
5. Collection and publication of vital statistics on health, etc.
6. Compilation and dissemination of public health information.

Our U. S. Public Health Service has been credited with the suppression of yellow fever in the South and control of bubonic plague in California, Puerto Rico, and Louisiana, which certainly justifies its existence. The importance of this Federal function cannot be minimized in view of the fact that good health is the first essential in any plan for a higher standard of living. The military leaders of Germany started a health movement as one of their first steps in the great military program that has come so close to conquering the entire civilized world.

Small nations have been wiped out by plagues, and even the most civilized nations today suffer a great loss of efficiency by the prevalence of diseases that fill our hospitals and reduce the efficiency of all workers. Poor health is a cause contributory to mental troubles and to all kinds of moral delinquency which fills our jails and other public institutions. If we can improve the public health, it will release hundreds of thousands of workers for more productive employment and will increase the productive working time of every citizen. This, in turn, will increase the wealth of the entire nation. It is difficult to conceive of anything that should be of more interest to the entire public and less subject to criticism than a program for public expenditures that will promote public health. In times of depression, the world is particularly vulnerable to epidemics and, even more so, following the ravages of war. The difficulty of providing proper facilities and maintaining public services enhances the possibilities of epidemics and, therefore, increases the necessity for public expenditures to promote better health.

In this field of public health service, there are two activities that are of vital importance to all mankind, and that cannot be separated. These are: the maintenance of a relatively pure water supply, and the proper disposal of sewage. Throughout human history, the improper disposal of sewage has been the greatest obstacle to providing a supply of good water. Water is absolutely necessary to all terrestrial life, but because water is a great solvent, commercially pure water is produced only in laboratories. We know that the water furnished a community will affect the vitality, the appearance, and the general health of the individual from the cradle to the grave; and it is a very important factor in the cost of living, especially when its neglect affects the length of life or reduces the energy and efficiency of the people. It has been demonstrated that a small amount of fluorine has a pre-natal effect on teeth, and in some communities, accounts for almost perfect teeth, with great resistance to decay; and, on the other hand, a very slight increase in fluorine content results in discolored teeth and dental difficulties of a very serious nature.

Every waterworks man is aware of the problems in maintaining a satisfactory water supply in his own community, but if he takes a transcontinental air trip by daylight, he will be profoundly impressed by the problems of other waterworks' men. He will see the clear blue water of the mountain lakes, such as Arrowhead and Tahoe; he will see the brown waters of the Missouri and the Mississippi; the red, green, and yellow waters, and the thick, white alkali waters of semi-arid states; the black waters of the forest states; and he will doubt that there is any color in the spectrum that cannot be found somewhere in this country in the raw water supply of some community. Because of its abundance, the old alchemists overlooked water as the universal solvent, but we know that sea water contains gold, magnesium, and nearly every known element; and chemicals dissolved in water constitute a great problem for waterworks' men. But chemical problems are no greater than bacteriological, vegetable, and potability problems. Tastes produced by algae are always a problem; and in all chlorinated waters containing phenol, we produce other tastes that are very objectionable, even when they are recognized as necessary to disease prevention.

The operator from the semi-arid states who flies over the Great Lakes may think that Chicago, Detroit, and Buffalo cannot have any water supply problems, but he will learn that they have many problems, most of which originated with careless sewage disposal. Millions of dollars are spent to make these waters potable, to remove certain chemicals, to supply other chemicals, and to provide the pressure to put the water where it is wanted. Millions more are required for disposing of waste water; and again, we find we cannot separate sewage disposal from water supply.

There is no place in this country where there is any excuse for wasting water. Regardless of its abundance in any locality, it must be distributed to the ultimate consumer; and waste requires an oversized system, which means a greater investment and, therefore, higher taxes. Waste water proportionately increases the size of the sewerage system, the cost of treatment, and the problem of disposal.

Experience in many communities has shown that the installation of water meters reduces water consumption by 20% to 50% by reducing waste and thus reduces proportionately the investment in water and sewage systems and the cost of treating and pumping both. Some sewage disposal experts are recommending meters on discharge lines, so that sewerage costs can be allocated according to actual use. Buffalo, where water is so plentiful, has the problem of reducing water waste or spending millions for more sewerage system capacity.

The requirements for relatively pure water are obvious in industry, beginning with the water supplied to steam boilers in our power plants and extending through the chemical industry, the paper industry, and the food industry as examples. Many industries that are interested in new locations are attracted or discouraged by the quantity and quality of the water supply. Furthermore, the supply is an indication of the efficiency of local government and of the economy and wisdom exercised by the citizens who are responsible for the election and appointment of officials who are so important to the public health and welfare. In many communities, it has been demonstrated that the savings due to water softening are reflected in the domestic soap requirements, and in war time, there is always a shortage of soap making materials. No one can say how much is lost by the more rapid deterioration of our clothing and other textile requirements when they are washed in hard water.

Infantile paralysis is an example of the epidemics of unknown origin that may be traced to water contaminated by sewage. Nearly every community has had occasional minor health disorders of epidemic proportion that are attributed to water contaminated by sewage. The subject of stream pollution is largely a matter of Federal regulation, because of its interstate character. Records indicate that sewage disposal plants can be self-sustaining, and there is accumulated evidence that some recovered materials may make an important addition to greater soil productivity, in addition to removing the most serious menace to public health. Many of our great river valleys, such as the Ohio, present horrible examples of good water sources continuously contaminated by sewage and other wastes. Communities near the source, using good water provided by nature, discharge their wastes downstream so that other communities, less fortunately situated, must spend enormous amounts of money for water purification; and they, in turn, discharge sewage into the same river to add to the problems and taxes of other cities downstream. It has been definitely demonstrated that the proper planning, construction, and operation of sewage disposal plants is one of the most profitable public enterprises that can be undertaken; but, in many cases, it is difficult to have one community assume the expense when it is obvious that the investment will benefit another community downstream.

As far back as 1892, there is a well authenticated record of water-borne disease being prevented by suitable water purification. The city of Hamburg took its water from the River Elbe and discharged its sewage into the river, and the downstream city of Altona had installed filtration more than forty years before. In 1892, Hamburg had 2,630 cases of cholera per 100,000, with a death rate exceeding 50%; while in Altona, the case rate was less than one-sixth as great and these few cases were believed to have been acquired in Hamburg. This demonstrated that a community, which protects its own interests, can only secure complete protection by aiding other communities with which it has contacts, whether upstream or downstream. We cannot guarantee public health if we do not help all our neighboring communities to solve their problems.

The record of the development of this country shows that the probable growth of nearly all communities can be forecast with reason-

able accuracy. However, there are very few instances where any community, large or small, has planned sufficiently well in advance for future requirements of water and sewage disposal. As a result, many communities have been burdened with heavy investments and heavy taxes, which certainly could have been drastically reduced if there had been real community planning. The City of New York affords a good example. Many millions are being spent, and many more will have to be spent in the near future, to acquire watersheds, transmission and distribution systems for the water supply, and still more millions for sewage disposal. The city has faced a dangerous shortage of water many times, because the increasing requirements have not been properly computed and the necessary advance steps have not been taken to provide facilities. The blame cannot be placed on the present administration, nor on any particular administration in the past. Every large city in the country, and many small cities, have spent very large sums in condemnation proceedings and legal battles to obtain additional water supplies, involving unnecessary millions of the taxpayers' money because of the failure to plan in advance for future needs.

If we have proved our case that water and sewage works should be planned in advance, and constructed whenever there is a slowing down of private enterprise, so that these public works can be used to take up the slack and take advantage of lower costs, the present problem is proper planning. A few months ago, Federal authorities advised post-war planning, but the sudden announcement of munitions shortages, linked with civilian manpower shortages, has brought the warning that we must devote every effort to winning the war; and surely no one will disagree with that conclusion. Nevertheless, there are many who cannot contribute directly to the war effort, but who are essential to our civilian activities. Among these are our waterworks and sewerage executives and engineers. The very shortage of manpower that eliminates ordinary replacements, maintenance and extensions, will give these men more time for planning post-war work. Some of them must devote their time during the war to take care of water and sewage problems involved in the housing of war workers in crowded defense areas, but there are many cities in which the planning of public works will not impede the war effort and will contribute

to the public welfare by reducing the problem of post-war employment. The great advantage of such public works planning is that it can be brought into use if unemployment is threatened and can be suspended if there is either a postponement of peace or a period of high employment following the peace.

An essential part of the planning is the best method of raising funds and making a proper return on the investment. There is no doubt that the best plans can be prepared by local authorities with professional advice, but they must often be coördinated with plans of other communities that have a mutual problem of water supply and sewage disposal. In some cases, this will necessitate Federal action, and this is the point where every community must take its stand on Federal aid.

The general opinion that Federal funds constitute a grab bag to which no particular community contributes, but in which every community should seek a large share, must be analyzed. This opinion has resulted in the waste of billions of dollars, starting with the extra cost of such funds, which cannot be explained better than in a speech made by Judge Hatton Sumners in Congress in 1921, in which he said:

> In the first place, if they (the States or communities) are to get money in this way, Congress must take some time to provide the appropriation and the people of the country have to pay for that. Then we send down to the States and get this money from the people by taxation. There is nowhere else to get it. We attach an overhead charge for its collection and the people have to pay for that. We bring it up here and cover it into the Treasury and the people have to pay for that. Then we send it out to the States and the people have to pay for having it sent back to the very place where we got it.

Fortunately for the nation, Representative Sumners is still in Congress, and he recently repeated his warning that the most expensive form of community enterprise originates with the demand for Federal funds. It was one of the most frequently expressed opinions of the founders of our Constitution that all possible Governmental powers should be delegated to the states and to local communities. It must be obvious to anyone that we cannot build up a staff in Washington large enough to plan the future needs of every community in the nation. If our public works are not properly planned, they are sure to be wasteful; and that means higher taxes for everyone. Fur-

thermore, if the appropriation of funds is made in Washington, it is almost certain that the allocation will be based on political considerations, rather than on the particular economic requirements of any community.

Any survey in any part of this country where Federal funds have been spent will show that billions have been wasted, either as a result of improper political considerations or impractical planning. You will find expensive post offices in tiny hamlets and antiquated post-office facilities in larger communities. You will find public roads representing an investment that will never be repaid by the traffic that is carried, and you will find other Federal roads that have to be widened and changed at enormous expense, because they were improperly planned for the loads to be carried. The Rivers and Harbors Bills passed by Congress have been denounced as pork barrels for a century. Everyone knows that millions have been spent for harbors that never had the commerce to justify the expenditure, because the politicians of the particular party in power wanted the good will of that area; while other harbors that should have been deepened have been neglected because the politicians felt that there were not enough possibilities for collecting a block of favorable votes.

If our people insist on Federal aid, we must expect more and more Federal domination of local affairs. The theory that the Federal funds are a boon to every community that receives them, is utterly untenable; whereas, Federal waste of any kind must be repaid by taxes that become an obligation of every citizen.

Our country has lived through many depressions, and it cannot be denied that they could have been lessened if we had planned public works projects and promoted them to prevent unemployment; and the cost of such measures would have been justified both by the low cost and the great saving due to anticipation of requirements.

When the planning and building of water and sewage works are carried out by local communities, it is certain that careful scrutiny by interested taxpayers will assure maximum results at minimum costs, provided that we have competent engineers and executives in charge. It is a public duty to see that the highest available type of skill is employed and properly paid for the planning and operation

of waterworks and sewage disposal plants. When such public works, as water and sewage utilities, offer the opportunity to save millions, improve public health, increase industrial efficiency, lower taxes, and vastly improve our standard of living, the only question that arises is: "WHAT ARE WE WAITING FOR?"

ENGINEERS AND ENGINEERING IN THE MASSACHUSETTS STATE BOARD OF HEALTH

BY GORDON M. FAIR*

[*Received December 6, 1944*†]

The story of public health in its modern implications, like that of other great social reforms, is the story of great men whose convictions and leadership, wisdom and toil, temporary failure and ultimate success fashioned a pattern of public opinion which could not be denied and now has left its imprint upon a century of human existence.

The public health movement, as we see it today, had its roots in the Industrial Revolution of the nineteenth century. Industry, the child of scientific discovery and invention, created the opportunity for mass employment. In the early stages of industrial development, limitations on the transmission of power and need for a nearby labor market forced the herding together of people in houses that clustered about the factories. To meet the rapid influx of workers, these mushrooming communities often could not expand their facilities fast enough to satisfy new and often frightening sanitary needs. In particular did the need for more abundant distribution of water, for more effective disposal of human wastes, and for more adequate housing force itself upon the attention of the thoughtful men whose duties, associations, or interests brought them into contact with the suffering of the masses of the people.

We can understand, therefore, why engineers were engaged from the very beginning in the modern public health campaign. The example for so doing was set in England during the Great Sanitary Awakening of the middle 19th century. There Sir Robert Rawlinson was employed by the General Board of Health in 1848 as Superintendent Inspector and in this capacity conducted the engineering

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†Address at meeting of the Massachusetts State Department of Public Health commemorating the 75th Anniversary of the Founding of the State Board of Health, the first State Board of Health in the United States of America. Prior publication in the New England Journal of Medicine is acknowledged.

studies necessary for the construction of sanitary works in growing industrial Britain. The real genius of British public health and the originator of many of its engineering advances, however, was Sir Edwin Chadwick. There is no gainsaying that the main threads of public health progress in Great Britain tie back to him. In the United States, these threads, too, can be traced to a single man: Lemuel Shattuck, like Chadwick neither a physician nor an engineer, but an enthusiast for sanitation. What Shattuck reports a London periodical of 1849 as saying about Chadwick* would seem to apply equally well to Shattuck himself: "He was not a man of varied or profound attainments, nor distinguished by any extraordinary brilliancy of intellect. But he was remarkable for his sagacity in extracting from masses of detail the master facts, and bringing these to bear for the elucidation of a master thought. He would confront, undaunted, any amount of intellectual labor; exploring mountains of blue books and statistical returns, till he had fully ascertained and brought to light their true riches."

Lemuel Shattuck's "Report of a General Plan for the Promotion of Public and Personal Health" was presented to the General Court of Massachusetts on April 25, 1850. His conclusions were based upon intensive studies of the sanitary movements abroad and at home. Because of the similarity in social background of the two countries, British experience, above all, influenced Shattuck's "Plan for a Sanitary Survey of the State." Among the measures advocated in this plan were the establishment of a General Board of Health, composed as far as practicable "of two physicians, one counsellor-at-law, one chemist or natural philosopher, one civil engineer, and two persons of other professions or occupations; all properly qualified for the office by their talents, their education, their experience, and their wisdom."* Two reasons were given why the members should not be selected exclusively from one profession: (1) Shattuck anticipated that numerous questions, requiring a knowledge possessed by different professions, would be presented for discussion and decision; and (2) the promotion of public health, in Shattuck's mind, was a matter which concerned every profession and every person. The services of medi-

*Report of the Sanitary Commission of Massachusetts, p. 29.
*Report of the Sanitary Commission of Massachusetts, p. 112.

cal men were indispensable; but the services of other professions, and of every person in their respective spheres, must be put in requisition, before reform could be complete.

The civil engineer member of the proposed Board, Shattuck suggested, should possess "competent knowledge to determine the best methods of planning and constructing public works, and the best architectural sanitary arrangements of public buildings, workshops, and private dwelling-houses."*

Although nineteen years elapsed before the Massachusetts State Board of Health was established and five more before John C. Hoadley of Lawrence was appointed engineer member of the Board, this recommendation of Lemuel Shattuck's seems to be the American wellspring of engineers in public health. About Hoadley, who served from 1874-1882, we know that he started his career as a civil engineer on the enlargement of the Erie Canal and was later placed in charge of locating, constructing and installing textile mills in Massachusetts. In the course of time his work with textile machinery turned him away from the field of civil engineering to that of mechanical engineering, in which he became expert. This shift in interest may explain why he did not provide the engineering leadership which he might have exerted in the new Board. An examination of the scientific articles and reports published in the regular series of Annual Reports shows but two articles over Hoadley's signature. During the same years the medical members of the Board were, indeed, more active in discussing engineering topics than was the engineer member himself. However, the Board employed as consultants some of the outstanding civil engineers of the period, in particular James P. Kirkwood, who was the first American engineer to build a filtration plant for water purification, and E. S. Chesbrough, who was to become celebrated for his designs of some of the great sewerage systems in the United States.

Investigations of the Board which involved problems of chemistry were generally assigned to Professor William Ripley Nichols of the Massachusetts Institute of Technology. Nichols, thereby, became the pioneer American water chemist. That the services of a chemist would be needed had been foretold, too, by Lemuel Shattuck, who

*Report of the Sanitary Commission of Massachusetts, p. 113.

wrote*: "Many questions relating to the influence of the elements on the production or prevention of disease, may require the special investigation of an experienced chemical philosopher, and this important branch of service should be ably represented at the Board."

It is a happy coincidence that in the same year in which the Board of Health was organized (1869) there was appointed as Chief Engineer of the Essex Company in Lawrence, one Hiram Francis Mills, then thirty-one years of age, for as we shall see the destiny of each was to be deeply influenced by the other. Hiram Mills was one of the first graduates of an American school of engineering, the Rensselaer Polytechnic Institute. He had worked with Kirkwood and also with Charles Storer Storrow and James B. Francis, chief engineers respectively of the Essex Company in Lawrence and the Merrimack Manufacturing Company in Lowell. These men were the leaders of hydraulic engineering in the New World. With the examples of Francis and Storrow before him, Hiram Mills early determined to prepare a treatise on hydraulics and set about gathering the necessary experimental information. When he became chief engineer of the Essex Company, the company which owns the dam and canal on the Merrimack river at Lawrence and controls the water needs of the manufactories, the opportunity presented itself to build a laboratory in which he could and did conduct his contemplated hydraulic researches. John R. Freeman, himself to become an engineer of distinction, was Mills' principal assistant for many years and has commented upon "the rare devotion of Mr. Mills to the search for scientific truth and deep insight, the untiring earnestness, and the consummate skill with which he carried on observations." This talent for research Hiram Mills carried with him when he was appointed a member of the State Board of Health in 1886, a fact which is probably responsible for the remarkable service that engineers, chemists and biologists were able to perform for the State under his leadership. Of Mr. Mills' association with the Board, which had been reorganized in 1886 under the chairmanship of Dr. Henry Pickering Walcott, Freeman writes as follows:*

"His profound interest and zeal as an investigator were then

*Report of the Sanitary Commission of Massachusetts, p. 113.
*Memoirs of the American Academy of Arts and Sciences, *15*, 2, p. 62.

awakened to the importance of advancing scientific knowledge in matters of purification of public water supplies and of prevention of stream pollution, and for about twenty-eight years this work of one kind and another for the Massachusetts Board of Health, for which he received no pecuniary compensation, absorbed a majority of his time, to the neglect of his earlier investigations in hydraulic science. . . ."

"Later, when in partial retirement long after he had passed three score and ten years he resumed this earlier task, failing strength prevented his continuing these hydraulic investigations or discussions on the scope originally planned."

Hiram Mills at the age of 80 years told Freeman with much feeling "that he 'had put off this work too long.' Nevertheless he collected his many notes and from day to day, up to his 84th year, worked over them patiently and steadfastly as many hours as his strength would permit, declining the assistance of younger eyes and hands."

Hiram Mills did not complete his notes for publication. They were made available to the profession by Karl R. Kennison, now Chief Engineer of the Boston Metropolitan Water Supply, as a Memoir of the American Academy of Arts and Sciences in 1924, three years after Mills' death.

But let us return to the memorable year of 1886. Along with the reorganization of the State Board of Health there was passed in that year a very important Act of the Legislature, entitled "An Act to Protect the Purity of Inland Waters." "Briefly, this Act placed in the hands of the State Board of Health the general oversight and care of all inland waters, directed that examination of the waters be made to ascertain whether they were adapted for use as sources of domestic supply or likely to imperil the public health, and that recommendations be given as to the prevention of pollution. Authority was given to employ expert assistance, and to conduct experiments to determine the best practicable methods of purification of sewage or disposal of manufacturing refuse. The Board was also ordered to give advice to cities and towns, corporations, and individuals as to sources of water supply and methods of sewage and refuse disposal, without expense to persons advised. Provision was also made for the

submission to the Board of all plans and schemes in relation to water supply and the disposal of drainage or refuse, for its advice. And, finally, the Board was ordered to bring to the notice of the Attorney General all instances of violation of the laws respecting the pollution of water supplies and inland waters."*

In order to carry out the provisions of this Act an engineering department was created in the State Board of Health, with Joseph P. Davis as Consulting Engineer, Frederick P. Stearns as Chief Engineer, and X. H. Goodnough as Assistant Engineer. Davis had been Chief Engineer of the Cochituate Water Board, the City of Boston, and the Boston Main Drainage System, and so brought to his consulting work a wealth of experience. Stearns directed the Engineering Department during its formative years and would probably not have relinquished his position to become Chief Engineer of the Metropolitan Water Board which constructed the Wachusett water supply for the Boston Metropolitan District had this enterprise itself not been one of the great projects of the State Board of Health. Goodnough succeeded Stearns in 1895 and, upon his retirement in 1930, passed on the reins of the Engineering Department to the present incumbent, Arthur D. Weston.

Along with the development of an engineering staff, the "Act to Protect the Purity of Inland Waters" had made available funds for the systematic analysis of water. This permitted drawing into close association with the engineers a notable group of chemists and biologists, some of whom were on the faculty of the Massachusetts Institute of Technology in whose laboratories the analytical work was performed until 1896, when a water laboratory was set up in the State House. In order "to conduct experiments to determine the best practicable methods of purification of sewage or disposal of manufacturing refuse," Hiram Mills placed at the disposal of the State Board of Health his hydraulic laboratory at Lawrence, about which we have already heard. This laboratory was renamed the Lawrence Experiment Station and has continued its useful existence ever since. As a laboratory for sanitary research, this station was the first of its kind, and its influence on the progress of sanitary engineering cannot be overestimated. To staff the station, Hiram Mills drew heavily

*Whipple, G. C., State Sanitation, vol. 1, p. 78.

on young graduates of the Massachusetts Institute of Technology who had come under the influence of teachers who were then active in the chemical and biological investigations of the State Board of Health.

Thus was initiated a decade of sanitary investigation the like of which has never been seen again in Massachusetts or anywhere else in the world. With the support of Dr. Walcott, and unified in their objectives by Hiram Mills' broad conception of what was needed in the task ahead, the Engineering Department, the Water Laboratory, and the Experiment Station collaborated with imagination and zeal to initiate great engineering enterprises, lay the foundation for sanitary analysis, and establish the experimental method as a means for determining the scientific and economic basis of public sanitation. The association of young men in this great adventure in sanitation appears to have been mutually so inspiring that there was to be hardly a man among them who did not make a significant contribution to the advancement of knowledge during his stay with the Board and who did not, as well, make a name for himself in later life.

A list of these men would include among others the names of:

Thomas M. Drown, chemist, successor to Professor William Ripley Nichols at the Massachusetts Institute of Technology and later President of Lehigh University;

William T. Sedgwick, biologist, later Professor of Biology at the Massachusetts Institute of Technology;

Allen Hazen, engineer investigator, later one of America's greatest practitioners;

George W. Fuller, chemist, who later at Louisville, Ky., laid the foundation for rapid sand filtration;

Gary N. Calkins, biologist, later Professor of Protozoology at Columbia University.

Edwin O. Jordan, bacteriologist, later Professor of Bacteriology at the University of Chicago; and

Harry W. Clark, chemist, later Director of the Water Laboratory and the Lawrence Experiment Station.

Notable among the great engineering enterprises of the group were the investigations that produced the Metropolitan Sewerage System of Boston, the Metropolitan Water Supply of Boston, and the Charles River Basin, public works that satisfied the highest standards

of engineering achievement and that continue to serve their intended function with success and distinction.

Many of the earlier studies of water purification and sewage treatment at the Lawrence Experiment Station are counted among the classics of sanitary literature. Some of them, in fact, were so fundamental and so well conceived that they have continued to be reprinted in books on Sanitary Engineering for half a century. The Lawrence Experiment Station eventually became a Mecca for engineers, chemists, and biologists interested in the purification of water, the treatment of sewage and industrial wastes, and the control of stream pollution. The Visitor's book of the Station is a veritable "Who's Who in Sanitation Throughout the World."

The fundamental organization of State sanitation initiated in 1886 has continued up to the present time. The Department of Health has undergone two major reorganizations, those of 1914 and 1919, but the Engineering Department itself has pursued the even tenor of its ways with little deviation from its original aims and objectives except as expanding interests have brought new and varied problems to its staff for solution. In the course of time, the Engineering Division has built up a record of service and a background of legal justification which are unique in public enterprise.

The coöperation between the Engineering Division, the Water Laboratory, and the Lawrence Experiment Station, which had been so fruitful during the early years of their existence, was allowed to become less close for a number of years. This worked particularly to the disadvantage of the Experiment Station which lacked the challenge of engineering problems to be solved in practice. During this period some of its investigations appear to have been less well conceived and executed, as well as less productive of useful results. This situation was remedied some years ago, and there are signs that the Station is on the way to recapture the fame and usefulness which it acquired during its first score of years.

The powers of the Division of Sanitary Engineering have been advisory in accordance with the general policy of the Department of Health. Only in times of severe stress has the "grammar of common sanitary legislation acquired the novel virtue of the imperative mood."*

*Simon, Sir John, English Sanitary Institution.

In this has probably lain the greatest incentive of the Division for service. Throughout its existence, the counsel of the Division has been sought as originally contemplated, and the record of applications for advice is one of steady growth. The construction of sanitary works in the Commonwealth has borne a direct relationship to the activities of the Division. This is exemplified by the progressive introduction of public water supplies. Prior to 1869 there were only 17 such supplies in Massachusetts; by 1890 this number had increased to 138; and by 1940 the 256 public water supplies of the State served no less than 97 percent of its total population. That these constructions were justified is shown by the declining annual death rate from typhoid fever. In 1873 this rate was 89 per 100,000 population; by 1890 it had dropped to 37; and by 1940 to 0.2.

Such is the story of engineering and its ancillary services within the Massachusetts State Board of Health. Needless to say, the work done has paid for itself over and over again in lives saved and sickness avoided, as well as in the general comfort and well-being of the people of Massachusetts. The influence of this pioneer engineering organization in a public health department, however, has extended far beyond the borders of the State and, indeed, beyond the boundaries of the nation. The published reports of the Board became one of the most important sources for sanitary information, and young engineers trained in the Engineering Division carried its spirit and its methods with them when they left to join or organize the engineering divisions of other health departments, to take part in the design and construction of great sanitary works, or to become teachers of sanitation in schools of engineering and schools of public health.

When Hiram Mills followed the injunctions of Lemuel Shattuck in his attack upon the fundamental problems of environmental control by putting in requisition the services of other professions in their respective spheres, he created, in fact, a new and important discipline of public health as well as engineering and a career to be embraced by young engineers who, like Chadwick and Shattuck, could become enthusiasts for sanitation. Collaboration in sanitary research for the solution of basic engineering problems established above all the desirability of equipping engineers with a knowledge of chemistry and biology, and the study of these subjects has since become a heri-

tage of sanitary engineers in America. The challenge that engineers could build disease or health into their works could either be turned aside by relegating responsibility for public health decisions to other professions—as was done and has very largely continued to be done abroad, and I may add with less success—or it could be accepted by acquiring an adequate fund of information to be able to evaluate the public health factors concerned. The engineers of Massachusetts chose to shoulder the responsibility themselves and so to play a significant part in the sanitary control of the human environment by engineering means.

After reviewing these contributions of Massachusetts to public health, I can find no more fitting expression for my own admiration of her accomplishments than is suggested by the last paragraph but one of Lemuel Shattuck's Report wherein, after enumerating the many ways in which Massachusetts has stood for social progress, Shattuck says:

"For these and very many other useful and honorable deeds, which might be specified, she has been named, by distinguished men of other states and countries, 'the forefather's land,' 'the moral state,' 'the enlightened state,' 'the patriotic state,' 'the philanthropic state,' 'the leading state,' 'the pattern state,' 'the noble state,' 'the glorious old Bay State,' "* And may I be permitted to add "the birthplace in America of public health and with it of the engineer in public health."

*Report of Sanitary Commission of Massachusetts, p. 306.

CROSS-CONNECTIONS AND BACK-SIPHONAGE CONNECTIONS UNDER WAR CONDITIONS*

[*Received February 23, 1945*]

Early in 1943 the Committee on Sanitary Engineering, Division of Medical Sciences, National Research Council, concerned itself with the general problem of cross-connections and back-siphonage connections under war conditions. The problems associated with this subject were aggravated beyond those normally encountered in peace time because of the large and rapid industrial expansion and the tremendous development in land and sea transportation for military purposes.

As a consequence of these unprecedented expansions, a number of public health disabilities were brought to the attention of the Committee. Prompt review of the whole situation was desirable in order to eliminate such hazards as were detectable and to prevent future accidents.

With this objective in mind, the Committee appointed, in accordance with its usual practices, a Temporary Subcommittee on Cross-Connections.

E. Sherman Chase	Raymond F. Goudey
Joel I. Connolly	Sol Pincus
Francis M. Dawson	Warren J. Scott, Chairman

The Subcommittee was requested to review the situation prevailing in 1943, to scrutinize such rules and regulations as had been promulgated by military, semi-military, and civilian agencies, to recommend modifications in policies and in practice on the part of these control groups, and to summarize its conclusions and recommendations for needed action.

The Subcommittee has been at work over a period of approximately a year. Many of its recommendations have been the subject of negotiation with the military and other agencies, with resulting adjustment in policies, regulations and practices.

*Sanitary Engineering Report No. 8, National Research Council, Division of Medical Sciences, acting for the Committee on Medical Research of the Office of Scientific Research and Development.

In order to make these findings more widely useful, the Committee on Sanitary Engineering has now agreed, with the approval of the National Research Council and the Surgeons General of the Army, the Navy, and the Public Health Service, to make these findings public. The following report presents the outstanding conclusions and recommendations currently adopted by the Committee on Sanitary Engineering.

For reasons of security and conservation of space, the appendices referred to in the Report are not herewith reproduced.

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REPORT OF SUBCOMMITTEE

This report of an investigation of the dangers that exist under war conditions because of cross-connections and back-siphonage connections with potable water supplies is submitted at the request of the Sanitary Engineering Committee of the National Research Council. A brief study of the subject is presented, together with recommendations for eliminating dangers to users of potable war supplies.

The present report brings up to date an earlier report made under date of 20 November 1943, which was later revised in a supplementary report dated 21 October 1944. The supplementary report cited further history and progress under war conditions since the time of the earlier report and reviewed the original recommendations. *While many of the conclusions and recommendations relate to programs that have similar considerations in war time and in peace time, the wartime aspect has predominating consideration in this report.*

DEFINITIONS

For the purpose of this report, the following terms are defined:

Potable pertains to water of safe, sanitary quality and approved for human consumption by the health or water authorities having jurisdiction.

Non-potable is the term applied to water which would be unsafe for human consumption.

Back-flow means the flow of non-potable water or other liquids into the distributing pipes of a potable supply of water from any source. The flow may be caused by gravity, vacuum, or other pressure differential.

Unapproved supply means a water supply which has not been approved for human consumption by the health or water authorities having jurisdiction. Many unapproved supplies used in industrial and in private fire protection work are unsafe for human consumption. Some well supplies, although of safe, sanitary quality, may be unapproved supplies in that they do not come under control of the public health or public water authority having jurisdiction over the public supply.

Cross-connection is defined as any physical connection, whether permanent or temporary, by means of which water may flow between a public or private potable supply and a non-potable or unapproved supply.

Back-siphonage connection is a water supply connection to a fixture, to a container holding unapproved water or solution, or to a drainage, soil, or waste pipe, so installed that unapproved water or material from the fixture, container, or drain may enter the water supply line.

Sewer connection is used to refer to any connection whereby potable water is directly connected to a sewer or drain.

Process-water connection is used to refer to any connection whereby potable water is connected to an industrial process water apparatus or tank so that process water may flow into the potable water line.

Inter-connection is used herein only to refer to connections between two potable water supplies.

Analysis of Types of Cross-Connections and Back-Siphonage Connections

As an example of the great extent of cross-connection and back-siphonage hazards, the following table shows numbers of violations of sanitary principles for the protection of water supply lines, as taken from the records of one large port city where a thorough study of conditions was made (1942-1943):

Number of industrial plants and military establishments	319
Cross-connections with non-potable water supplies	331
Process-water connections	2,861
Sewer connections (to water supplies)	627
Back-siphonage connections with plumbing systems	6,777
Back-siphonage connections (miscellaneous)	3,365
Pierhead connections (unequipped with protective devices)	1,115
Total	15,076

The Peace-Time Problem

Cross-Connections. Cross-connections have for many years been the subject of study by waterworks and health officials. Many of the serious water-borne outbreaks in the last two decades have been due to cross-connections whereby non-potable water has entered potable water systems. These cross-connections, when not the result of carelessness or poor design, are made usually for standby fire protection, for industrial water use, for pump priming, or for auxiliary boiler feed. Reports and recommendations have been prepared by the American Water Works Association, the New England Water Works Association, the Conference of State Sanitary Engineers, and other interested groups. In a comprehensive review of a seven year period ending in 1936 in the United States, Wolman and Gorman* state that of 170 reported water-borne outbreaks, 14 were due to cross-connections with a polluted water supply. A preliminary tabulation of disease outbreaks conveyed through water in the United States in 1942, as reported to the U. S. Public Health Service by state and territorial health authorities, indicates that of 50 reported water-borne outbreaks, eight were due to cross-connections with a polluted water

*Annual Year Book, American Public Health Association, Vol. 20, No. 2.

supply. The Surgeon General of the U. S. Public Health Service on 11 January 1930, issued a communication to all state health officers, stating that cross-connections with potable water systems supplying interstate carriers and non-potable water systems or supplies must be controlled or eliminated to warrant full certification.

In most instances, except for auxiliary fire protection, the peacetime remedy of separation has been relatively simple through the use of tanks filled from overhead connections or through swing connections. Correction of cross-connection conditions on industrial fire-protection systems has sometimes been difficult because of weaknesses in public supplies from a fire-protection standpoint. This has unfortunately led to a weighing of pollution and disease hazards against fire-loss hazards. A committee of the American Water Works Association states: "It must not be forgotten that, in the United States, fire now takes a toll as great as, if not greater than, does typhoid. . . . It is, of course, problematical how many lives are lost in fires as the result, direct or indirect, of inadequate water supply—probably not a great many. On the other hand, it is true that uncontrolled fires offer a hazard to life as well as to property. Bearing this fact in mind, health authorities must recognize that protective measures against fire serve also in some degree to save life."

This statement is presented because a distortion of the picture along this line from the standpoint of fire protection is referred to later in a discussion of war-time conditions, since such distortion may bring about serious hazards to the public health. It should be borne in mind that one case of typhoid fever may be the focus of many other cases and deaths, so that direct comparisons with injuries or deaths from fire do not present a clear account of the consequences.

Great progress has been made in eliminating cross-connections in the past two or more decades. Unquestionably many thousands of dangerous cross-connections have been broken through coöperative action and through passage and enforcement of cross-connection regulations. Some of these regulations have been adopted by states. Examples are the California and Connecticut state regulations. Numerous local water and health departments (*e.g.*, Los Angeles) have also adopted rules and regulations. It must be admitted, however, that enforcement often falls far behind the setting up of control pro-

cedures. State health agencies usually do not have the personnel to carry out the detailed and continuous follow-up necessary. Local water or health agencies may shirk their responsibilities and fail to carry out the necessary detailed surveys and subsequent reappraisals of conditions. Finally, it must be conceded that even with conscientious attempted supervision, new cross-connections or concealed connections may give trouble.

Double check valves of approved type, with specially designed clearance, facings, seats, and covers have met with a considerable measure of success in preventing back-flow into potable water supply systems. Published records of inspections by the Associated Factory Mutual Fire Insurance Companies and the Connecticut State Department of Health covering large numbers of check valve installations over a period of years indicate that a great degree of reliance can be placed on double check valves. However, Connecticut prohibits new check valve installations, although continuing old ones under approved conditions. New York requires that where check valves are used, the auxiliary unapproved supply be equipped with an automatic chlorinator as an additional factor of protection. In some states, check valves are not allowed at all. The experience does not favor dependence on check valves of less than six-inch size.

In 1941, a committee of the American Water Works Association reported that in 28 states cross-connections were under definitely established rules and regulations and that in 20 states they were controlled only under general powers. The committee considered that in 26 states control was "good," in 17 states control was "fair," and in five states control was "poor." While some improvements may have been effected since 1941, sanitary control of cross-connections was far from perfect prior to the outbreak of war. It is to be noted that most studies of cross-connections such as that of the A.W.W.A. committee have not included connections with used or circulated water, originally from a potable water supply but later rendered nonpotable. This field needs further investigation.

Back-siphonage Connections. Back-siphonage connections between potable water supply lines and plumbing systems may actually admit sewage to water lines under certain hydraulic conditions. In hospitals, equipment may be used with submerged inlets and connec-

tions so installed that infectious or poisonous materials may be back-siphoned into the potable water supply pipes. Submerged inlets to factory process tanks holding poisonous solutions may result in contamination of the potable water supply should back-siphonage occur. It is readily conceivable that opportunities for sabotage may exist because of back-flow of dangerous solutions in industrial plants.

The number of back-siphonage connections is so vast and the possibilities of isolated instances of sickness through them so great that any estimate of the damage done through them must almost rest in the realm of conjecture. If we call peace-time cross-connection control in the nation only "fair" or "far from perfect," we might readily designate peace-time back-siphonage connection control as "poor."

Dangerous back-siphonage conditions are caused through improperly designed fixtures, through undersized or overloaded water piping, or through improperly installed piping. Considerable progress has been and is being made in the manufacture of fixtures which will not permit back-siphonage. Comparatively little has been done to eliminate old faulty fixtures. Some effort has been made to prevent new bad installations. Plumbers through their organizations have tried to promote safer practices both through the use of tested and approved fixtures and through control of plumbing by licensing and adoption of adequate codes. Certain health departments, notably in some of our large cities and in some of our states, have done commendable work.

Water utilities, by and large, have not entered forcefully into the field of back-siphonage control. This is perhaps due to the fact that they may consider their job is done when they pipe safe water *to* the property line or building, and they may contend that it is up to the public health authorities to take steps to protect the safety of the water in the buildings under private ownership. Of course, the public water supply mains may be infected through back-siphonage connections even though most frequently the damage may be limited to the users in the buildings where the faulty back-siphonage connections are located.

It is unfortunate that few states as yet have adopted state plumbing codes, because this would do much to eliminate back-siphonage hazards. While local communities have in many instances adopted

excellent codes, much progress remains to be made. Sizes of water piping, methods of installation, and piping use are not adequately covered in many local codes.

Time does not permit a complete review of the many dangerous occurrences in this field of back-siphonage connections but reference is made to a bibliography on "Plumbing and Public Health" prepared in mimeographed form by Arthur P. Miller, Sanitary Engineer, United States Public Health Service, New York City, in 1940. This includes 360 references to published papers and discussions.

Changed Conditions in War Time

The number of dangerous cross-connection and back-siphonage connection conditions has unquestionably increased due to (1) a large number of new industrial plants, (2) enlargements of old industrial plants, (3) changed processes in industrial plants, (4) demands for increased fire protection by war agencies, and, (5) increased shipping activities. The speed necessary in war-time construction is a factor that may lead to oversight or neglect of necessary health precautions. The evidence is that the war impact may have entered this field especially in (1) permanent cross-connections for auxiliary fire fighting supplies from unapproved sources such as in industrial plants, (2) temporary cross-connections for auxiliary fire-fighting supplies from unapproved sources either through "siamese" or other connections in factories, docks, or vessels, (3) permanent or temporary cross-connections with auxiliary unapproved water supplies used for industrial work or during construction, (4) permanent or temporary cross-connections with auxiliary unapproved water supplies used for pump priming or boiler feed in industries, (5) back-siphonage connections through submerged inlets in industrial process tanks filled with poisonous solutions, and (6) back-siphonage connections with plumbing systems or special service fixtures in new or enlarged industrial plants, hospitals, or other public buildings. The great increase in concentration of workers in factories and in the populations of our cities means that adverse effects from pollution of water will now be far more extensive than in peace-time.

Inspectional facilities by supervisory local and state agencies since the advent of war have been reduced by personnel depletions;

military and industrial construction undertaken by the Federal government may not have always been subjected to local or state official scrutiny or local or state regulations; many of the personnel assigned to operating water supply connections and equipment are not adequately instructed and supervised; shortage of materials for pipe, valves, pumps, storage tanks, and other structures that might readily eliminate the need for cross-connections has resulted in dangerous short cuts and practices not normally adopted; such military considerations as protection against sabotage or possible sudden loss of valuable materials and equipment may have actuated adoption of measures that would not have been countenanced by the agency in peace-time. All of these factors when super-imposed upon the imperfections of peace-time protective measures have unquestionably produced serious hazards that merit attention and action.

The Record of War Agencies and Industries

Some evidence has accumulated to indicate that, as a result of changed conditions in war time as just discussed, some of the principles and standards regulating practices in the field of cross-connections and back-siphonage connections with potable water supplies during peace time are being abrogated in one direction or another during war time, with possible serious risk to industrial workers, members of the military forces, and the general public. This Subcommittee at the time of its first report on 20 November 1943, endeavored to explore this field by communicating with a selected group of officials who, because of their geographical locations or special activities, might be most likely to furnish data based on experience. It was not attempted to assemble any complete summary of waterborne outbreaks which since the advent of war might be attributed to cross-connections or back-siphonage connections. Rather it was attempted within a very short time to secure a few representative examples from sections of the country, preferably spread among establishments under the control of a number of war time agencies. The Subcommittee has not considered it necessary to re-tabulate the data obtained and bring the record up to date, inasmuch as a sufficient cross section of experience is recorded in the data below, although it should be noted that despite steps taken by the armed services and

various administrative agencies since the issuance of the earlier report serious instances of back-flow contamination of water piping systems have continued to occur, especially at ship-side outlets and on vessels.

The 1943 returns from the selected individuals or members of the Subcommittee cover conditions in Alabama, California, Connecticut, Illinois, Louisiana, Maine, Massachusetts, Missouri, New Hampshire, New York, Ohio, Pennsylvania, and Texas. Some of the general situations were covered by letter. The returns from Alabama, Connecticut, Maine, Massachusetts, Missouri, New Hampshire, New York State exclusive of New York City, Pennsylvania, and Texas reveal no specific examples of outbreaks of disease as a result of cross-connection or back-siphonage conditions brought about because of the war. However, returns from New York City, Chicago, California, Louisiana, and Ohio do show that serious outbreaks of disease have occurred. A tabulation of returns from questionnaires has been prepared.

These returns are discussed under sub-headings below. Twenty instances of examples of dangerous conditions are cited in the returns.

Reports of Water Pollution by Pumping Into Mains. Of a total of eleven reported examples, eight instances of pumping polluted water into drinking-water mains were at pierhead connections; two were in industrial plants; and one was the action of a construction contractor. Of the eight instances referred to, four were under the jurisdiction of the U. S. Navy, two under the jurisdiction of Navy and Maritime Commission, one under the Maritime Commission, and one was on an Army transport.

Back-siphonage Connections with Plumbing Systems. Seven instances of serious back-siphonage connections with plumbing systems are reported where the evidence indicated that pollution flowed from plumbing systems to contaminate water supply lines. Two of these instances were in connection with industrial plants having war contracts or were close to military establishments; three were in Army buildings; two were in buildings housing Army students.

Back-siphonage Connections with Process Water. One instance of back-siphonage of process water, possibly containing dangerous chemicals, into potable water supply lines is cited in an industrial plant.

Report of Employee Filling Water Containers. One instance is reported in a shipyard where an outbreak of disease was caused by the filling of water barrels with polluted water.

Disease Outbreaks Noted in Returns. The returns below indicate the occurrence of twenty disease outbreaks, reported to be distributed among establishments serving various Federal agencies, as follows:

Four—U. S. Navy—New York City, San Francisco, San Diego, Los Angeles—minimum of 1065 estimated cases of gastro-intestinal disease.

Two—U. S. Navy and Maritime Commission—San Pedro, Terminal Island—estimated several thousand cases of gastro-intestinal disease.

Two—Maritime Commission—Stockton, Wilmington—minimum of 200 cases of gastro-intestinal disease.

Five—U. S. Army—New Orleans; Los Angeles, 4—minimum of 200 cases of gastro-intestinal disease, 2 deaths.

Four—U. S. Army Air Corps—Los Angeles, 4—minimum of 600 cases of gastro-intestinal disease.

Three—War Industry—New York City; Chicago; St. Mary's, Ohio—2225 cases of gastro-intestinal disease.

Due to censorship, exact figures of the number of persons made sick or exposed to disease outbreak are missing in many instances. The tabulation (not reproduced) indicates that a total of about 100,000 persons were exposed to disease hazards.

Disease Outbreaks from U. S. Public Health Service Tabulation. The tabulation of disease outbreaks in 1942 prepared by the U. S. Public Health Service and previously referred to indicates the occurrence of two water-borne disease outbreaks which were apparently in establishments or industries associated with the war program and which were apparently due to cross-connections or back-siphonage connections on properties served, as follows:

One—Shipyard—Superior, Wisconsin—13 cases of gastro-intestinal disease.
One—Shipyard—Camden, N. J.—447 cases of gastro-intestinal disease.

Unreported Instances of Pollution Through Pierhead Connections. It is the belief of this Subcommittee that many cases of serious pollution of potable water lines have occurred without being reported to any civilian agency. It is difficult for this Subcommittee to obtain information from the military agencies in war time as to cases where improper use of pierhead connections may have caused pollution of water supply lines.

Back-siphonage Connections in Military Hospitals. The dangers of back-siphonage pollution from hospital fixtures undoubtedly may

exist in military hospitals, but this Subcommittee does not know how extensive an attempt has been made to check the existence of such dangers and eliminate them.

Pierhead Connections

Pierhead connections presumably installed to supply the vessel with potable water for drinking or for fire fighting do provide a ready method of polluting potable water. At pierheads, the use of auxiliary fire pumps for non-potable water, either situated on vessels or on shore, frequently through temporary hose lines, may result in pollution of potable water in one of the following ways: (1) cross-connections made between potable water lines on a vessel and non-potable water in a fire line or sanitary system of a vessel whereby the vessel potable water supply may be polluted; (2) cross-connections made between potable water line on shore and non-potable water on fire line of vessel whereby non-potable water may be carried to other users of the potable water system including this and other vessels; (3) cross-connections made between potable water line on shore and non-potable water in shore fire line whereby non-potable water may be carried to potable water system of users of water at pierhead; (4) cross-connections between potable water line on shore and a stand-by pump on auxiliary supply vessel or elsewhere, such pump being used to increase the speed of water supply to the ship being serviced. The dangers of cross-connections at pierheads are aggravated when there are a number of vessels using common pierhead outlets.

Steps Taken by Federal Services

Since the date of issuance of the original report, information has reached the Subcommittee with regard to certain steps taken by Federal services in connection with prevention of back-flow contamination. These are discussed below.

U. S. Coast Guard. The U. S. Coast Guard has issued a set of instructions to reduce the danger of occurrence of back-flow contamination, especially with relation to fire service.* These instructions include directions for maintenance of fire service connections

*Amendment of Section 6.355 of "Regulations for the Security of Vessels in Port."

from the potable water supply line (1) when vessels are with power and (2) when vessels are without power. The principal weaknesses of these regulations are that they place complete dependence upon manual operations and upon instructions that are likely to be disregarded in the case of fire service and that they do not cover adequately the use of water for domestic service. It is only fair to state, however, that these regulations have been a definite step forward and have afforded substantial reduction in the hazard of back-flow contamination through fire services.

U. S. Army. The Army Service Forces have issued a set of instructions somewhat similar to those of the U. S. Coast Guard, but these later regulations include improvements in that they cover the question of protection of domestic water service and call for the installation of back-flow preventive devices when connections are made with ship fire pumps inoperative. In reviewing these regulations, it is recommended that Section 4 be changed to eliminate the words "or after the vessel's pumps become operative," inasmuch as this wording may lead to confusion in interpretation.

The sanitary programs of the Provost Marshal and the Surgeon General of the U. S. Army, the Army Air Forces, and other procurement agencies have included the inspection of the water piping systems of military establishments and thousands of war production plants. These programs were well conceived and were productive of much good in reducing back-flow hazards although lack of personnel has limited the scope of coverage.

U. S. Maritime Commission. While this Commission, so far as the Subcommittee knows, has issued no directives to all of its personnel regarding control of back-flow hazards, excellent coöperation has been given to local programs in some sections of the country, such as along the West Coast.

U. S. Navy. The Subcommittee is informed that the Navy is now giving consideration to the preparation of a memorandum to its personnel which would call attention to the hazards of contamination from back-flow and would present instructions relative to installation of back-flow preventive devices where needed.

U. S. Public Health Service. The new water supply standards promulgated by the Surgeon General for interstate carriers have em-

phasized the need for control of back-flow contamination and have tended to direct additional attention to the subject.

Methods of Prevention of Back-Flow into Potable Water Systems

Varying degrees of protection against back-flow of non-potable water or other liquids into the distributing pipes of a potable supply of water have been sought in the following ways:

Method 1. Physical separation with a safe air gap as specified in "American Standard Air Gaps in Plumbing Systems"* (approved by American Standards Assn., 1942).

Method 2. Use of a vacuum breaker installed on the discharge side of the last separating control valve and so placed that there is no back pressure when the normal flow ceases (see specifications approved by American Standards Assn., 1943**).

Method 3. Use of a back-flow preventer which operates under pressure and which has a central zone between check valves or equivalent in which zone the pressure would at all times be maintained less than the pressure on the potable side; with a relief opening from the central zone to atmosphere discharging the following minimum quantities without the pressure in the intermediate zone exceeding the pressure on the inlet side for any pressure on the inlet side greater than one-half pound per square inch:

Size of Device Inches	Capacity Gallons Per Minute
1	6
2	16
3	25
4	35
6	60
Larger	100

Method 4. Use of double check valves of 6-inch size or larger, designed and installed to seat readily and completely and equipped for testing, as approved by the health or water authorities having jurisdiction.

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*ASA (A 40.4 - 1942).
**ASA (A 40.6 - 1943).

Method 5. Use of single check valves on 2-inch lines and larger, accessible for inspection. For ship-side outlets, such valves should be connected with short nipples and installed on a slant of 10 degrees from the horizontal, so as to permit ready inspection and complete drainage.

Supplementary Protective Steps. In the application of the above methods it may also be desirable in certain instances as supplementary protective steps to install differential pressure vacuum breakers in locations where vacuum relief is necessary, or safety valves to guard against excessively high pressures such as above 175 psi. For 2-inch or smaller pipe, vacuum breakers should have full-size opening equivalent to the circular area of a diameter equal to the size of the pipe; for pipe over 2 inches in size, an opening equal to a circular area with 2-inch diameter is acceptable. Safety valves should comply with A.S.A. standards.

Conclusions and Recommendations

Following are the conclusions and recommendations of this Subcommittee. The "methods" referred to are described previously under "Methods of Prevention of Back-flow into Potable Water Systems."

1. It is recognized that the ultimate ideal in the field of cross-connection control is to develop potable water supply distribution to the point where auxiliary water supplies are not necessary, but this ideal cannot prevail at ship-side locations. Moreover, in addition to cross-connection considerations, the possibilities of back-siphonage with plumbing systems, process water systems, and sewer systems exist. This Subcommittee recommends that steps be taken to protect back-flow connections between potable and non-potable water supplies including those at pierheads and industrial water-using processes and between potable water supplies and sewers or drains.

2. Personnel assigned to operating water supply connections and equipment should be adequately instructed and should be supervised at all times; such personnel should be furnished a clear statement as to duties and responsibilities with respect to the protection and safety of the water supply.

3. Every connection with a plumbing system which will permit back-siphonage should be eliminated when possible; otherwise it

should be provided with an approved type of vacuum breaker.* Whenever there is possible occurrence of vacuum in a water pipe, means for rapid dissipation should be provided.

4. Every process-water connection should be separated from the potable water supply by Method 1, unless due to local conditions or as a temporary measure Methods 2 or 3 are permitted by the local water and health authorities having jurisdiction. Process water connections should receive attention both within and without buildings and include connections to process water tanks and recirculating systems.

5. Every direct cross-connection between potable water lines or apparatus holding potable water and sewers or drains should be broken, and air gap separation should be used.

6. Where pipes for potable and non-potable water exist, such as in industrial plants or on vessels or docks, pipes should be so painted, posted, or otherwise marked as to be distinguishable readily; where possible, all outlets of non-potable water lines should be made unavailable for drinking. All shore connections into which fire boats may pump should have distribution systems separate from systems carrying potable water.

7. In many cases the inadequacy of pipe lines conveying water to pierheads from approved sources has tended to promote the use of unapproved auxiliary water supplies at pierheads. It is recommended that federal agencies institute a survey of water and distribution pipe adequacies at pierheads.

8. During the war emergency, protection of the shore users near pierhead connections should be afforded at or near the property line by Methods 3 or 4 on domestic and fire lines carrying potable water.

9. *In addition to protection at the property line,* back-flow preventive devices should be installed at each ship-side outlet, whether for domestic or fire service. Method 3 represents the best type of protection and should be used for protection of each individual ship-side outlet on fresh water fronts where freezing temperatures are not encountered and so far as practicable at all other locations. However, under some conditions, modifications of the use of Method 3

*ASA (A 40.4 - 1942; A 40.6 - 1943).

may be desirable so that the following substitute methods are considered permissible for the following conditions:

Pierheads in locations on fresh water fronts where freezing temperatures are encountered. Method 3 to be installed on all lines leading to individual piers (except when there is only one pier and the pipe line entering the property is already protected by Method 3) and Method 5 to be installed on each individual ship-side outlet.

Pierheads in locations on salt water fronts. Method 5 installed on each individual ship-side outlet is minimum protection. This affords less protection than Method 3 and is distinctly inferior, but a considerable degree of reliance can be placed on the prompt detection of contamination when due to salt water. Protection of lines leading to individual piers is desirable but is not considered mandatory at such locations.

10. All cross-connections between potable and non-potable water supply lines on vessels should be broken and so maintained, as outlined in the current regulations of the U. S. Coast Guard and the U. S. Army. If in an extreme emergency a cross-connection is made on a vessel between a potable and a non-potable water supply, immediate steps should be taken to notify all persons against use of water without being boiled, and all pipes and tanks contaminated should be disinfected after the emergency cross-connection has been broken. Supervisory medical officers or health authorities should be notified as to the cross-connection.

11. The use of double check valves as a method of prevention of back-flow described in Method 4 is inferior as a substitute for Method 3, even on 6-inch water lines or larger, despite the fact that such valves where given adequate maintenance and supervision have been used with a considerable measure of success on many old installations. The weakness of double check valve protection *per se* is that the forces responsible for back-flow—pressure differential and vacuum—are not destroyed.

12. In connection with the use of the "Methods" referred to in the above recommendations, there may be certain instances where special supplementary protection against vacuum or against excessively high pressures should be afforded to aid in back-flow prevention. Because of the many varying conditions encountered, no attempt is made to cite such special locations, but "Supplementary Protective Steps" are discussed under "Methods."

13. All back-flow preventive devices as listed herein should be selected on the basis of approved design supplemented by operating experience under varying conditions and should be tested and approved by laboratories of recognized national standing with experience in this field. Devices should be designed with due regard to possible effects of corrosion, incrustation, or other deterioration and should be so constructed as to be inspected and repaired readily. Back-flow preventers should be properly installed under competent supervision in such a manner that no back-flow of contaminating substances through ports or pipes in the devices is possible under any hydraulic conditions. Approved preventers should be marked as to make, type, size, and direction of flow.

14. Attention is directed to the need for careful installation of back-flow preventive devices to avoid introduction of contamination by the devices themselves. They should be installed where possible above flood level. Where this is not possible, special precautions should be taken. All devices should be installed so as to be readily accessible for testing and inspection and should be properly equipped for necessary testing. Internal inspection and repair should be carried out at least annually, and tests should be made on a more frequent basis.

15. Effort should be made by federal agencies to promote adoption of state and local codes controlling water piping and plumbing.

16. Local water, health, and building departments should cooperate, and establish a coördinated program to investigate and correct existing dangers from back-flow and to control new installations of water and plumbing systems in buildings. Local inspection staffs can undoubtedly be employed to good advantage in this field.

17. The appropriate federal agencies should establish a unified national program and work with state and local agencies to correct and control dangerous back-flow conditions. Such a program should include the principles and procedures outlined in this report. Specific regulations and instructions for responsible federal personnel should be adopted, and these should cover instructions to the level of the water foremen and engine-room workers on vessels. Training courses for personnel are needed and should be established.

RESPONSIBILITY FOR WATER PIPING ON CONSUMER PREMISES

BY WARREN J. SCOTT*

[*Read February 15, 1945.*]

The subject of responsibility for water quality beyond the point where the public water supply system is extended on consumer premises is one that has been widely discussed in recent months.

United States Public Health Service Standards. The official 1942 Public Health Service Drinking Water Standards in Section 1.6 define a water supply system as including "the works and auxiliaries for collection, treatment, and distribution of the water from the source of supply to the free-flowing outlet of the ultimate consumer." They state further in Section 2.2 that "The water supply system in all its parts shall be free from sanitary defects and health hazards and shall be maintained at all times in a proper sanitary condition." Although the standards promulgated by the U. S. Public Health Service relate only to water supplies furnished for drinking and culinary purposes to common carriers in interstate commerce who are required to supply water in conformity to the standards, such standards have through application and usage come to be construed as official national standards that should be met by all water utilities. Certainly such has been the case with the former water quality standards developed by the U. S. Public Health Service in 1914 and revised in 1925, which did much to promote improvement of water supplies in this country. The percentage of water supplies in each state that are furnished to interstate carriers varies widely. The following table has been prepared with the kind coöperation of the sanitary engineers of the New England States, to cite New England conditions:

	No. of Public Water Supplies	No. of Supplies Certified For Interstate Carrier Use	Percentage Certified
Connecticut	110	11	10
Maine	162	18	11

*Director, Bureau of Sanitary Engineering, Connecticut Department of Health, Hartford, Conn.

	No. of Public Water Supplies	No. of Supplies Certified For Interstate Carrier Use	Percentage Certified
Massachusetts	256	36	14
New Hampshire	124	12	10
Rhode Island	47	3	6
Vermont	170	12	7
Total	869	92	11

When operating managements, after consideration, realized the implications of the responsibilities thrust upon them by literal interpretation of the 1942 standards, they properly objected. At a conference between public health representatives and water works representatives held in April, 1944, to consider objections raised, the U. S. Public Health Service evidenced a desire to coöperate in an endeavor to arrive at a satisfactory answer to the objections. Subsequently, on September 1, 1944, the U. S. Public Health Service issued an official interpretation of the Public Health Service Drinking Water Standards in Circular Letter to State Health Officers No. 85. This letter states that a reasonable application of Section 2.2 of the standards, for purposes of certification of common carrier water supplies, would be:

"(a) Strict application insofar as practicable under existing conditions of Section 2.2 to collection, treatment, and distribution works from the source to the meter or connection to the customer's premises.

"(b) A sincere effort on the part of municipal, county, and State authorities having jurisdiction toward the elimination of sanitary defects and health hazards as defined in Sections 1.4 and 1.5* (which include cross connections and back-flow connections) from the water distribution system within the customer's property.

"(c) Assurance after careful investigation by the Reporting Agency* (which is the state department of health) that such sanitary defects and health hazards probably do not exist on any water service line used for delivering drinking water to common carrier conveyances. The investigation of such water service lines should include the entire system served by them beginning with their first point of connection to the water mains of the public water supply system."

*Explanations in parentheses were inserted by the writer.

It is further stated in this letter that the "sincere effort" referred to above may be considered to have been made if it can be shown:

"1. That satisfactory rules and regulations covering connections or arrangements by which unsafe water may be discharged or drawn into the water supply system are applied to all new construction, that remedial measures are taken as promptly as material and labor are available to correct plumbing defects which have come to the attention of the local officials, and that a continuing program is instituted to detect hazards on the system.

"2. That evidence is presented indicating that surveys have been made to locate cross-connections between the main supply and auxiliary supplies or any other supply of liquids or chemicals of unknown or questionable safety and that active steps have been taken to eliminate or safeguard any such connections found."

If either (1) or (2) above is deficient, the state agency is advised that provisional certification should be recommended with a definite time limit specified for compliance with Section 2.2 in accordance with these criteria.

In the writer's opinion it is somewhat unfortunate that the standards themselves have not been modified along the lines of the interpretive comments contained in Circular Letter 85. The underlying difficulty is the attempt to write into a standard having the status of a governmental regulation the delegation of responsibility for maintenance of conditions which are admittedly desirable but which are difficult of practical attainment, certainly under existing machinery for control.

Cross-Connections Back-Siphonage Connections, and Sewer Connections. It is of interest that the Manual of Recommended Water Sanitation Practice published in company with the Public Health Service Drinking Water Standards states in Part III, Section C, that "House or industrial toilet or sink fixtures capable of back-siphonage into the water system should be classed as cross-connections. . . ." However, a distinction is frequently made between (1) cross connections, (2) so-called back-siphonage connections, and (3) sewer connections. For the purpose of discussion in this paper the following terms are used:

Cross-Connection is defined as any physical connection by means of which water may flow between a public or private potable supply and a non-potable or unapproved supply.

Back-Siphonage Connection is a water supply connection to a fixture, to a container holding unapproved water or solution, or to a drainage, soil or waste pipe, so installed that unapproved water or material from the fixture, container, or drain may enter the water supply line.

Sewer Connection is used to refer to any connection whereby potable water is directly connected to a sewer or drain.

That there is a definite public health hazard from cross-connections between potable water supplies and non-potable water supplies has long been recognized, and most states now have regulations prohibiting such cross-connections, at least unless guarded by approved protective devices, such as double check valves properly installed and subject to regular testing and inspection. Many water-borne epidemics have been caused by cross-connections. Much progress has been made in their elimination. In the writer's own state, it can be said with assurance that thousands of cross-connections have been discovered and broken in the past two decades. Yet new illegal connections continue to crop up to a limited extent.

Under war conditions, the ever-present danger from cross-connections at ship-side locations along water fronts has been increased, as evidenced by numerous reported outbreaks of illness. Better instruction and supervision of dock and ship workers are needed, and the installation of back-flow protective devices at ship-side locations is desirable, to guard the public water supply lines against inadvertently made cross-connections with unapproved water supplies at docks and on ships.

Back-siphonage connections with plumbing fixtures or industrial process water tanks, or sewer connections, as distinguished from cross-connections between potable and non-potable water supplies, are less likely to create epidemics, although there have been serious outbreaks of sickness from such connections and the danger is always there. The fact that the pressures on the side of the back-siphonage and sewer connections, where the polluting materials are, are generally low as compared with the normal water pressure, has undoubtedly kept serious disease outbreaks to a minimum, but it is well known that especially in high buildings water pressures on upper floors may

at times be low or even non-existent, and in other locations water pressures may suddenly drop with the result that polluting material may be sucked into the water supply lines. The writer has seen instances where water has been sucked out of a flooded toilet bowl without a vacuum breaker on the water line, and out of bath tubs with submerged inlets, to pollute building water supply piping. How many sporadic cases of sickness may be caused by plumbing fixtures, sewer connections, or industrial process connections, none of us knows.

Where the Responsibility Lies. The questions naturally arise as to where the responsibility lies and how the dangers may best be eliminated. The legal side of the subject is discussed at some length in a paper by John H. Murdoch, Jr., in the *Journal* of the American Water Works Association in August, 1944. He states in this discussion:

"Where dangerous defects are known to exist or where the water supply operators are in position to know of such defects by exercising ordinary powers of observation and deduction, the water supply operators are in duty bound to take steps to guard against contamination of the general supply. There is, however, no legal or moral obligation on a water works operator to undertake the impossible task of inspecting all consumers' premises for sanitary defects. Indeed, there would seem to be a moral obligation to make it plain to all concerned that such inspections are not made and that, so far as the water supply agencies are concerned, the limit of the public water supply system is the property line."

Mr. Murdoch is probably justified in this statement wherein he disclaims an obligation on the part of the water works operator to carry out inspections to detect all sanitary defects of piping systems on private property. At the same time, he points out that there is a responsibility on the part of the water utility to seek the remedy of known defects.

Methods of Correction. The following questions arise in relation to the correction of existing conditions:

1. What regulations are or should be applicable to the correction of cross-connection, back-siphonage connection and sewer connection hazards?

2. Who is in a position to undertake the investigational and corrective work on existing piping systems?

3. Who is in a position to pass on plans for new piping on private premises?

It is, of course, essential that either state or local regulations be enacted both to prohibit cross-connections between potable and non-potable water supplies and to prohibit back-siphonage and sewer connections whereby polluting material may be drawn into lines carrying potable water. If it is possible to provide for regulation either through a state sanitary code or state plumbing code, which is enforceable by local authorities, this would seem to be the best answer to the first question. If it is not practicable to provide for control through state regulations, consideration should be given in each local community to the possible enactment of ordinances or regulations, possibly through the local plumbing code.

There are in Connecticut, Regulation 118 of the sanitary code prohibiting cross-connections and Regulation 127 of the sanitary code prohibiting back-siphonage connections and sewer connections; the latter regulation has been applied largely to new installations so far as plumbing fixtures are concerned but can be applied to existing fixtures. The sanitary code is enforceable by local health officers.

In considering agencies that might carry out inspection of existing piping systems, there come to mind the state department of health, the local department of health, the local building or plumbing inspector, and the water utility. The paper in this issue of this JOURNAL by D. C. Wiggin entitled "Recent Survey of Interior Water Piping in Connecticut" indicates what we have been trying to do in Connecticut, largely by and under the direction of the State Department of Health, although in some cities, especially the larger ones, we have had assistance from local health authorities. We have had excellent cooperation and much assistance from local water utilities. Obviously, our surveys covering so many systems must take a long time. Also, these surveys can be repeated only at very infrequent intervals unless somebody becomes generous and provides us with a large inspection staff.

I feel that the state department of health should not shirk its responsibilities and should make every effort to advise and assist

local authorities. In Connecticut, we are even going so far as to take responsibility for initial surveys in industrial establishments and large buildings and for inauguration of corrective steps in our communities. Industrialists have been most coöperative. These surveys of water piping must be repeated, and they should gradually be extended so far as possible to smaller properties. It seems to the writer that this continuing survey work should be undertaken locally. Unfortunately, some local health departments, especially the smaller ones, often do not have the trained personnel to make such surveys. We have promoted inspections by local health departments in our largest cities, have instructed some local inspectors, and have cooperated with them on solution of difficult problems arising from their own investigations. There is no question but that the water utility is often best equipped from the standpoint of technical knowledge to make such surveys, even though it may lack personnel and may disclaim legal responsibility for such activities.

It is emphasized that the water utility has moral responsibilities. If the water supply in a building becomes polluted, the water supply outside the premises may become polluted, and this is certainly a cause for concern on the part of the water utility. The U. S. Public Health Service is properly concerned about the public health danger from cross-connections and back-siphonage connections and so are the state health departments. It is of no avail for the water utility to bury its head in the sand and say, "It's none of our business." It is their business to display interest and to endeavor to work out some plan of correction.

It is difficult to suggest any cure-all. It does seem to the writer, however, that the problem should be approached at the local level. Possibly the local health department personnel can be instructed so as to carry out inspections; the local water utility may help them. Arrangements may be made for the local plumbing or building inspector to do the work. The appointment of a local committee to study the problem may lead to the development of a satisfactory local program. Possibilities for the membership on such a committee are the local health officer, the superintendent of the water utility, the superintendent of public works, the city engineer, and the plumbing or building inspector. The state department of health can be depended

upon to coöperate to the extent of its personnel, even though it does not seem fair nor reasonable to expect them to undertake the carrying out of periodic local surveys to detect and eliminate new cross-connections and back-siphonage connections.

Our Department recommends in its regular reports to water utilities that they carry out periodic surveys to attempt to detect and eliminate cross-connections, and many of them do this; others, however, do not. Connecticut water utilities are prohibited by the sanitary code from furnishing water to premises where cross-connections exist. We have not asked water utilities to carry out detailed surveys to detect back-siphonage connections with plumbing systems, process water tanks, etc.; they probably would object to such a request, and so might their customers. But the water utility has an interest.

The formation of a local committee might also lead to the answer to the last question presented by the writer, which is the delegation of responsibility for approval of plans for new water piping on private premises. We do have plumbing inspectors passing on sewer lines. Why not cover the still more important water pipes? In New Bedford, Mass., Stephen Taylor inaugurated a local plan for approval of new water piping.

Conclusion. There is a decided public health danger from cross-connections, back-siphonage connections, and sewer connections with public water supply systems. Public health authorities are endeavoring to assist in elimination of dangerous connections. State agencies, while doing their part, cannot handle this problem alone. The proper approach is at the local level with such state guidance and assistance as is practicable.

The water utility has a decided interest in effecting improvements. There is a moral responsibility even where there may not be a legal one. The water utility should periodically survey its distribution system to detect and eliminate cross-connections with non-potable water supplies. The water utility should also point the way in endeavoring to promote a satisfactory local arrangement for periodic surveys to detect and eliminate back-siphonage connections and for passing on plans for new water piping systems.

Discussion

Arthur D. Weston.* In opening this discussion I shall not attempt to cite instances of cross-connection or back-siphonage conditions in Massachusetts, because the files of the Journal of the New England Water Works Association are filled with excellent reports of committees on those subjects and also with papers that, together with the excellent papers of Messrs. Wiggin and Scott, complete that picture. However, I would like to emphasize the fact that, so far as Massachusetts is concerned, this problem is one which is definitely subject to regulatory control.

In the first instance, as Mr. Scott has mentioned, we have what is known as the United States Quarantine Regulations. These regulations require the United States Public Health Service to determine the character of the water that is to be used by common carriers. That is where their responsibility ends. However, they pass the responsibility over to the states. Mr. Scott mentioned that only about ten per cent of the water departments in the various New England states are subject to the United States Quarantine regulations, but he failed to point out that the ten per cent include, as a rule, the largest water supplies, so that a comparison of the amount of water actually delivered would show that nearer 75 to 80 per cent of the water supplied is regulated in this manner.

We come next to state laws and state regulations. These include the laws regarding water departments, both the General Laws and their enabling acts. In practice, under the enabling acts of recent years, the water departments have sole responsibility for the distribution of water and its character, subject to any state control which might be given under the General Laws. Local water departments can't refuse to accept that responsibility, and they should exercise it. However, it is surprising to see how few water departments appreciate the fact that they are responsible for conditions beyond the source of supply. They do not realize that they really are responsible for the condition of the water in any place, even in private buildings whence impure water may get into the mains and contaminate the supply. There also rests with water departments authority under the General Laws, so that either by the General Laws or under separate

*Boston, Mass.

enabling acts they have a tremendous amount of responsibility, which they should exercise.

We have a law in Massachusetts which gives certain authority for the regulation of plumbing by communities. For municipalities of 4,000 population or under, the state examiners of plumbers, on application by the local board of health, may adopt rules and regulations, and those rules and regulations, when approved by the State Department of Public Health and accepted by the municipality, have all the force of law. For municipalities of 4,000 or over, the municipality must adopt some form of rules and regulations, but the enforcement of those rules and regulations, under Section 13 of Chapter 142 of the General Laws, is the responsibility of the building inspector, if there is a building inspector, and if not, of the board of health.

The latter law is rather tricky regarding the responsibility of the board of health, or the building inspector, so far as plumbing rules and regulations are concerned. They relate only to "waste water," and I want to emphasize that point. The law definitely says "waste water." The board of health, in other words, in their regulations, have absolutely no control of the water piping system inside private premises. On the other hand, in the enforcement of their plumbing rules and regulations, they can rightfully demand a type of connection to any sanitary fixture which will not result in back-siphonage of waste water. In this way they enter indirectly into the water department's field. It is just a question of where the dividing line on the fixtures is between the sanitary or waste side and the water side. The water department, on the other hand, would have no control over the fixture itself, the design of which they might not like. Their control would nevertheless have to stop with the water supply, but they could control and forbid the connection if it did not have a proper siphon breaker on the line.

As far as the State Department of Health is concerned, the state may make rules and regulations for the protection of the water supply. That is a very broad power. However, in the interpretation of the law, we have come to the conclusion that it is our responsibility only to protect the public water supply through large connections. In other words, it is obvious that where a fire service connection exists and also where industrial connections of considerable size exist, there

are definite hazards to the public water supply which are a responsibility of the state in part. We have left it to the local authorities to handle the small back-siphonage conditions and the small cross-connection conditions in buildings, either to the water department or possibly, in the case of sanitary fixtures, to the board of health.

In regard to the remark that is sometimes voiced, "Isn't it much ado about nothing, this whole question of cross-connections and back-siphonage connections," I don't think that any of us appreciate fully what the probable effect is upon the public health. We become definitely interested when we have an epidemic involving several hundred or several thousand people, but we have little or no knowledge of the rather considerable number of cases of infection throughout a municipality which can be caused by cross-connections but which do not in any way resemble an epidemic. It is just as important to protect several hundred people in the municipality, scattered here and there, as it is to consider the several hundred people who are definitely ill in one group identified as an epidemic. We find conditions in water plants themselves which are definitely hazardous and we find conditions in municipal sewage pumping stations which are also definitely hazardous. While the hazards and difficulties are more often found on private property, they are also to be found on public property.

SURVEY OF INTERIOR WATER PIPING IN CONNECTICUT

BY DAVID C. WIGGIN, JR.*

[*Read February 15, 1945.*]

In 1937, the Connecticut State Department of Health began a survey of interior water piping in the larger cities and towns of the state. This survey has been carried on with occasional interruptions since that time. The purpose of the survey was to detect within buildings hazardous piping connections that might, under certain conditions, endanger the drinking water, and to eliminate these connections or sources of possible contamination. It is recognized that although the domestic or drinking water may be derived from an approved source, it may become contaminated within a building because of unprotected storage tanks, by cross-connections with secondary supplies of a non-potable nature, through back-siphonage from submerged inlets to process water tanks or vats, and by direct connections to sewers.

Scope of Survey. In making a survey of interior water piping in a community, it is, of course, necessary from a practical standpoint to make certain limitations in the extent of inspections, although theoretically it would be desirable to inspect every building. For the purpose of this survey, it was decided to include all factories and industrial establishments, laundries, theatres, hotels, bottling plants, pasteurization plants, buildings over three stories in height, and stores with two or more floors. The idea was to include those customers who might use water for other than simple domestic purposes or who might have drinking-water storage tanks.

When the survey was originally begun in 1937, a representative of the State Department of Health visited the local health departments in the larger cities where full-time inspectors were available. At first a sanitary engineer of the State Department of Health accompanied the local inspector for one or more days to point out some of

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the undesirable conditions to look for. The local health departments in ten of the larger cities made the survey within their cities and took steps to correct the hazardous conditions.

In 1940 and 1941, a sanitary engineer of the State Department of Health continued the survey in six other cities, which did not have qualified inspectors. The survey was discontinued at that time because of the added duties of this agency in the war effort. Later it was felt that the danger was increased because of the many changes due to war production, and the survey was again continued in 1943. An attempt was made to include especially those communities that were important centers of war production. This paper will include only the results of the survey from 1943 to the present time. During this period, 26 towns were surveyed. The field work was largely done by Roscoe J. Kent, Sanitary Engineer of the Connecticut State Department of Health, with considerable follow-up work by the writer. A survey of all towns with a population over 5,000 persons has almost been completed and will be extended to the smaller communities soon. A few small suburban towns have already been surveyed to complete metropolitan areas.

Procedure. The procedure followed was generally standardized. Before a survey was begun, a sanitary engineer of the State Department of Health visited the town to be surveyed and discussed the problem with the local health officer. Often a local health inspector was available to accompany the state engineer on the inspection. In some towns, a representative of the water department in the town was a companion of the state engineer. Local participation is very desirable, because in this way a local representative has the hazards pointed out to him, and this assists him in having them corrected. Very good coöperation was obtained both from local health departments and from the water utilities. This is very important, because surveys should be repeated periodically by some local agency.

The procedure called for a listing of all establishments to be visited, and this was done in coöperation with the local officials. Then, on a visit to the plants for the inspection, the sanitary engineer talked with each plant superintendent, engineer, or master mechanic, and visited every fixture that was supplied with water.

An inspection form was provided to guide the engineer in his

questioning. It covered: sources of water supply, drinking water storage tanks, cross-connections, submerged inlets to process tanks or vats, and direct connections to sewers. These subjects will be discussed below. A summary of the various types of connections found in the survey is shown in the accompanying table.

TYPES OF CONNECTIONS FOUND IN CONNECTICUT SURVEY OF INTERIOR WATER PIPING

Town	1940 Census Population	No. of Bldgs Inspected	Cross-Connections with Non-Potable Supplies	No. of Submerged Inlets to Tanks, etc.	No. of Direct Connections to Sewers
A	68,685	34	3	108	5
B	39,849	104	5	78	32
C	30,167	42	8	44	5
D	30,021	44	1	14	2
E	23,373	31	2	34	3
F	22,580	37	3	20	6
G	21,135	25	0	5	1
H	19,210	19	5	2	2
I	18,615	28	2	125	1
J	16,439	32	3	10	0
K	15,388	17	7	18	2
L	14,788	37	0	9	2
M	13,561	13	3	0	0
N	10,910	9	1	4	2
O	10,287	21	3	3	0
P	9,094	4	1	5	0
Q	8,978	19	1	9	0
R	8,787	11	3	2	0
S	8,482	26	3	20	0
T	8,258	11	1	0	0
U	8,060	12	0	3	0
V	6,632	12	3	5	0
W	5,449	7	1	0	0
X	5,230	18	2	1	0
Y	4,352	7	1	0	0
Z	2,009	4	0	0	0
Total		624	62	519	63

Sources of Water Supply. The answers to this first question enabled the inspectors to obtain a general picture of the water supplies by checking the source of water for (a) Drinking, (b) Hand Washing, (c) Process or Industrial Use, (d) Boiler, (e) Toilets, (f) Fire. Of 624 buildings inspected in 26 towns, it was found that 474 buildings used the public water supply for all purposes with no secondary supply available; 142 buildings had secondary supplies from wells, rivers, or reservoirs that were used in conjunction with the public water supply; and 8 buildings had no public water supply available and depended on private water supplies for all purposes.

Drinking-Water Storage Tanks. Drinking-water storage tanks should be properly covered. No sewer should pass over them, and there should be no other possible sources of contamination. The tank overflow and drain pipes should not be directly connected to a sewer.

Only five drinking-water storage tanks were found in the 26 towns; of these, one was not properly protected. The wooden cover of the faulty tank was not tight, and the overflow and drain pipes were connected directly to the sewer. The tank was located in the basement of a factory building. The water was pumped from the tank to drinking fountains throughout the factory. During the conference with the plant superintendent, following the inspection, it was recommended that the drain and overflow pipe be provided with an open connection to the sewer. It was suggested that the pipe should discharge into a funnel or sink instead of being directly connected to the sewer. The plumber at the factory, who accompanied the engineer on the inspection, commented that this could not be done, because if the sewage backed up, it would overflow onto the floor. The plant superintendent dryly commented that it would be better to have the sewage back up onto the basement floor rather than into the drinking-water storage tank.

Cross-Connections. Under cross-connections are included all physical connections between a public water supply, or a private drinking-water supply, and any secondary supplies of a non-potable nature. Sixty-two cross-connections were found in the course of this survey, varying in number from zero in some towns to as many as eight in one town. In addition to these physical connections, 71 temporarily

broken cross-connections were encountered. These constitute a hazard to the drinking-water supply, because when the second supply is needed, a physical connection is made that may result in contamination of the drinking-water supply under some conditions. Such connection, after the need is over, are not always immediately broken, and the hazard continues beyond the time of the temporary hook-up.

A cross-connection was found at one plant in which the public supply was supposedly protected by means of three valves with an open drip between two of them. When it was recommended that this physical connection be broken, the plant superintendent suggested that although he had three valves, he was willing, if necessary, to install three or four more valves in the pipe line. The inspector reminded him that when it was desired to use the public water supply, all valves would be open, whether there were three valves or six valves.

The best method for eliminating cross-connections is to provide an auxiliary tank filled from above the rim with water from the public system. This may not, of course, always be feasible. Reduced pressures or possible freezing are the most frequent objections. Other less satisfactory arrangements include:

1. The swing connection with an elbow and union so placed that either of the two water supplies can be fed into the private system without it being possible for both supplies to be used at once.

2. The single filler piece made up of unions or flanges and used to fill either of two similar breaks, one in the potable water supply line and one in the auxiliary water supply line, in such a manner that in one position, the potable supply will be served, and in the other position, the auxiliary water will be served, without it being possble for both supplies to be connected together. It is important that a duplicate filler piece should not be provided.

3. Recently, a device known as the Sure-Shift Interconnector (manufactured by the Industrial Interconnector Company, 2150 Niagara St., Buffalo 7, New York) has come on the market to afford an automatic means of shifting the use of water with an open break to separate water supply sources, but as yet no installations have been made in Connecticut.

Submerged Inlets to Process Tanks or Vats. The investigation

was limited to tanks or vats used for process water or mill use, and no attempt was made to check on the domestic use of water in fixtures such as toilets, lavatories, and bath tubs because of the magnitude of the task involved. It is felt that the hazard of these fixtures has been considerably reduced during the past few years, by the replacement of potentially dangerous fixtures with approved ones, which provide vacuum breakers and over-rim inlets.

A total of 519 submerged inlets were found, chiefly in plating-rinse tanks, quenching tanks, and water-operated cellar drainers. They were chiefly located in certain communities doing plating work, and it is of interest that of this number, 125 submerged inlets were found in one town and 108 in another. These conditions can be corrected by cutting off the water supply inlets above the rim of the tank or, if submerged inlets are desired to obtain stirring or circulation in the tank, by providing vacuum breakers on the feed lines above the tank to prevent back-siphonage.

Direct Connections to Sewers. These include any physical connections between the public water supply and a sewer line. Sixty-one such connections were found in this survey, chiefly on cooling-water lines for compressors and condensors, fire sprinkler blow-off lines, hydraulic presses, and hydraulic elevators.

These situations can be corrected by breaking the connection to the sewer and providing an open break to a funnel or tank. In this way, if the sewer backs up, sewage cannot pass into the water supply lines.

Steps Taken to Eliminate Piping Hazards. At the time of the inspection, the possible dangers of the piping hazards and the means for correcting them were discussed with the plant officials. Almost always, the plant officials agreed to correct the conditions in a satisfactory manner.

After the survey had been completed in a town, individual forms were filled out in duplicate for each building where any objectionable conditions were found, stating the piping hazard encountered and the recommendation for its elimination. Copies of recommendations were given both to the local health department and to the water utility. Also summary sheets were prepared listing the buildings and the piping hazards found. The local health officer was also given copies

of the state sanitary code regulation pertaining to these hazardous piping connections.

Cross-connections were given special attention, because these present a definite hazard to the public water supply as well as to the drinking water within the building. Cross-connections are expressly prohibited under the State Sanitary Code. All cross-connections were referred to the water utility with recommendations for their correction. The utility was asked to report to the State Department of Health when an inspection by the water utility indicated that the cross-connection had been corrected in a satisfactory manner. In case of question or difficulty, a sanitary engineer of the Connecticut State Department of Health made a reinspection with an official of the water utility.

An example of back-siphonage dangers found by the writer is the back-siphonage due to corroded pipes discovered in an apartment house in a large Connecticut city. Tenants had complained of lack of water pressure. A bathtub, with an under-rim inlet and located on the third floor, was filled with water. A heavy dose of chlorine was added to the water by the writer as the tub was filling, and the tub was filled to submerge the water supply inlet. On opening a lavatory faucet on the second floor, water was siphoned out of the tub and a high chlorine residual test was obtained at the sink. This demonstration immediately convinced the owner of the need for prompt remedial measures.

Conclusion. The survey indicates that a considerable number of hazardous piping connections exist in the interior of buildings. The connections not only endanger the drinking water within the premises but may also, under certain conditions, contaminate the water in the mains of the public water supply. The only protection afforded in many cases is the maintenance of normal pressure on the public water supply pipes. Normal water pressure cannot be depended upon within a building, however, because piping partially clogged as a result of corrosion may produce negative heads in the upper floors of buildings at times of heavy use of water. Also the normal pressure in the mains of the public water supply may be lowered by a large fire or a bad break in the system.

The only proper way to correct the hazards described is to elim-

inate the condition at the source of contamination by doing away with unprotected drinking-water tanks, unprotected submerged inlets to process tanks or vats, direct connections to sewers, and cross-connections with secondary supplies.

APPLICABILITY OF OXIDATION POTENTIAL MEASUREMENTS IN DETERMINING THE CONCENTRATION OF GERMICIDALLY ACTIVE CHLORINE IN WATER*

BY SHIH LU CHANG†

[*Received February 5, 1945.*]

It has been the experience of most investigators who have studied the disinfection of water by chlorine and its compounds that the germicidal efficiency of these substances varies widely under different conditions. The chief factor influencing the efficiency is the pH of the solution. Next in importance is the presence of ammonium and organic substances that combine with chlorine to form chloramines. Such great variations in germicidal efficiency have been observed for solutions in which the amounts of residual chlorine determined by the conventional acid starch-iodide or ortho-tolidine methods differed very little, that doubt has been cast on the practical value of these conventional methods for reflecting the true killing activity of chlorine and compounds. Because they were dissatisfied with current methods, a number of investigators have studied the possibility of using oxidation potential measurements to evaluate germicidally active chlorine.

Since the time of Jakowkin's work (1), it has been known that when gaseous chlorine dissolves in water, it hydrolyses into hypochlorous and hydrochloric acids. The amount of hypochlorous acid formed is governed by the equation

$$\frac{(HOCl)(H^+)(Cl^-)}{(Cl_2)} = K_h \qquad (1)$$

where the parentheses represent the concentrations of the compounds or ions and K_h is the hydrolysis constant. The value of K_h given in the International Critical Tables is 4.48×10^{-4} at 25 °C. From

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Equation (1), it is apparent that the completeness of hydrolysis depends on the *pH* and the chloride and chlorine concentrations of the solution. It has generally been implied from Jakowkin's Work that while in very dilute solutions of gaseous chlorine hydrolysis is nearly complete, several hours may elapse before equilibrium is reached. Recently, however, Kolhatkar and Sant (2), by measuring the conductivity of a solution of gaseous chlorine, found that the hydrolysis is practically complete in a few minutes. Measurements of the hydrogen-ion concentration with a glass electrode, have satisfied the writer that equilibrium is reached in about 5 minutes at concentrations of titratable chlorine as high as 1,500 p.p.m.

Hypochlorous acid is a very weak acid and dissociates into H^+ and OCl^- ions (the dissociation of $HOCl$ into HO^- and Cl^+ ions is doubtful and is not considered here) according to the equation

$$\frac{(H^+)(OCl^-)}{(HOCl)} = K_d \qquad (2)$$

where K_d is the dissociation constant. This constant is given as 2.95×10^{-8} at 18 °C by Ingham and Morrison (3), 3.16×10^{-8} at 20 °C by Shilov (4), and 5.6×10^{-8} at 25 °C by Skrabal and Berger (5).

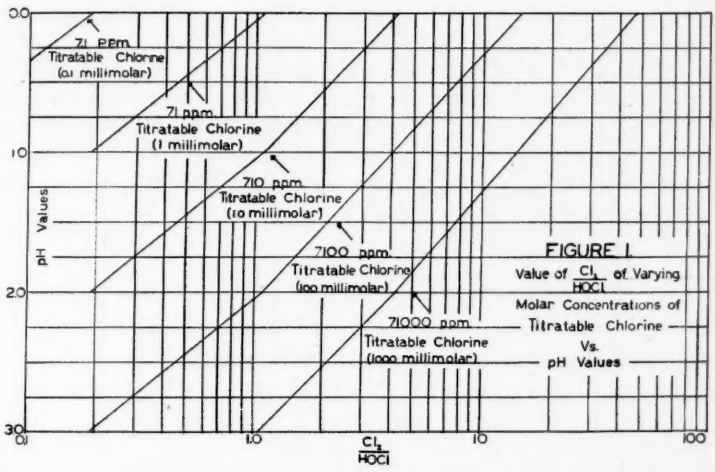
In order to show the relative amounts of Cl_2 and $HOCl$ in a chlorine solution at varying *pH* values, the following stoichiometric equation can be derived:

$$\frac{Cl_2}{HOCl} = \frac{-\left(1 + \frac{K_d}{H^+}\right) \pm \sqrt{\left(1 + \frac{K_d}{H^+}\right)^2 + 4C\frac{H^+}{K_h}\left(1 + \frac{K_d}{H^+}\right)}}{2} \qquad (3)$$

where K_h is the hydrolysis constant of Cl_2, K_d is the dissociation constant of $HOCl$, and C is the molar concentration of gaseous chlorine. Since the value of K_d is very small and Cl_2 exists only at relatively low *pH* values, the equation may be simplified as follows without introducing significant errors:

$$\frac{Cl_2}{HOCl} = \frac{-1 \pm \sqrt{1 + 4C\frac{H^+}{K_h}}}{2} \qquad (4)$$

The values of the ratio of $Cl_2 \div HOCl$ at different molar concentrations and *pH* values from 0.0 to 3.0 have been calculated and are presented in Figure 1. The percentages of Cl_2 and *HOCl* in different



molar concentrations of chlorine and *pH* values estimated from this diagram are found to agree quite closely with those reported by Jakowkin. From Figure 1 it is apparent that even with a solution containing 71 p.p.m. of titratable chlorine at pH 2.0, only about 2% of the chlorine exists as Cl_2 when equilibrium is established. Also, it is apparent that in the ordinary process of chlorination of water the amount of chlorine applied is so small, while the *pH* is rarely below 5.0, that the amount of Cl_2 existing in such a solution may be neglected, except that some Cl_2 may exist for a very brief time when gaseous chlorine is used.

At *pH* values above 5.0, dissociation of *HOCl* becomes appreciable. The percentages of *HOCl* and OCl^- at *pH* values between 3.0 and 11.0 and temperatures of 18, 20, and 25 °C are calculated from the respective dissociation constants and are presented in Figure 2.

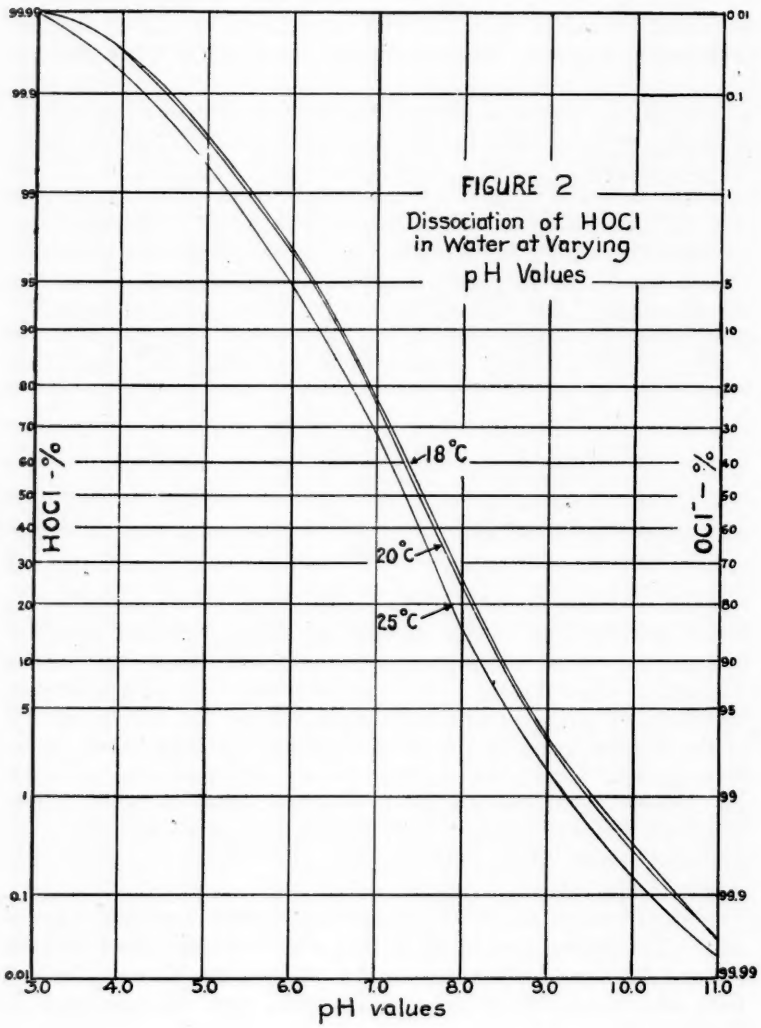


FIGURE 2
Dissociation of HOCl in Water at Varying pH Values
HOCl - %
OCl⁻ - %
18°C
20°C
25°C
99.99
99.9
99
95
90
80
70
60
50
40
30
20
10
5
1
0.1
0.01
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
pH values

In an earlier paper the writer (6) has shown that the cyst-penetrating and cysticidal activities (referring to cysts of *Entamoeba histolytica,* the resting stage of the causative organism of amoebiasis and amoebic dysentery) of a solution of gaseous chlorine or calcium hypochlorite depend on the relative amounts of Cl_2, $HOCl$, and OCl^- present in the solution. The Cl_2 is the most cyst-penetrating and most cysticidal component, the $HOCl$ slightly less so, and the OCl^- apparently non-cyst-penetrating and non-cysticidal. As illustrated in this paper (6), the increase in the titratable chlorine necessary to kill all cysts when the *pH* is increased is just sufficient to maintain the amount of $HOCl$ at a definite cysticidal level. This conclusion is based on the fact that the amount of $HOCl$ calculated from the residual chlorine at cysticidal levels and at varying *pH* values was found to be fairly constant for each particular temperature and contact period.

In the same paper (6), it was also shown that di-chlor compounds such as Halazone (p-sulfone dichloramido-benzoic acid) and dichloramine ($NHCl_2$) are less cyst-penetrating and less cysticidal than Cl_2 and $HOCl$ and that mono-chlor compounds such as monochloramine (NH_2Cl) and succinchlorimide are still less cyst-penetrating and cysticidal. In another paper by the writer (7), data were presented indicating that, in a *pH* range of 8.5 to 8.8, the cysticidal efficiency of calcium hypochlorite was about the same as, if not less than, that of monochloramine (NH_2Cl). Apparently this is due to the very small amount of chlorine existing as $HOCl$ at such high *pH* values.

In the light of these studies, it is clear that in determining the amount of residual chlorine for interpretation of germicidal or cysticidal efficiency, an ideal method would be one that would not only differentiate chlorine from chloramines but also active (Cl_2 and $HOCl$) from inactive (OCl^-) chlorine. Under some conditions, a fairly accurate estimate of the Cl_2 and $HOCl$ present in a chlorine solution may be made from the constants that have been given, provided that the total titratable chlorine and *pH* are known. However, the estimate is of practical value only when the tests are made in relatively pure water containing negligible amounts of ammonia- or organic-nitrogen, so that the formation of chloramines is eliminated.

Interpretation of Oxidation Potential Measurements for Germicidally Active Chlorine

As early as 1913, Rideal and Evans (8) originated the oxidation potential concept of the process of chlorination of water. These authors observed that substances like chlorine have high oxidation potentials which can be indicated electrochemically, and they felt that the amount of active chlorine might be measured by the potential created in the solution. Schmelkes (9) found that the oxidation potential of hypochlorite solutions at different *pH* values paralleled bactericidal activity, and that both oxidation potentials and bactericidal efficiencies increased from azochloramid through chloramine-T to hypochlorite in water not containing large amounts of organic material. The later work of Schmelkes and Horning (10), which showed the reversal of the bactericidal efficiency of these three chlorinating agents in water containing 10 and 50 per cent serum was quoted by Levine and Charlton (11) as evidence of the unreliability of the oxidation potentials as measures of germicidal chlorine. This criticism, in the writer's opinion, seems unjustified, for the high oxidation potential of a solution of a chlorinating substance does not necessarily mean that the latter must be highly germicidal in all circumstances. In fact, the higher the oxidation potential of the compound, the less may be its germicidal efficiency in water containing concentrations of organic material as high as 10 and 50 per cent serum, since the active chlorine (*HOCl*) would either be reduced to chloride by, or form chloramines with the serum proteins.

Remington and Trimble (12) determined the oxidation potentials of hypochlorite solutions and found that bubbling oxygen gas through the solution resulted in no significant changes in the potentials measured by a smooth platinum electrode; but that bubbling CO_2 gas through the soultion markedly and steadily increased the potential as the *pH* lowered from 12.0 to 5.0. Their observations can be reasonably explained by the fact that most solutions, unless properly prepared and kept, tend to contain dissolved oxygen in equilibrium with the partial pressure of oxygen in the atmosphere and that they form an oxygen electrode. Since oxygen dissolves very slightly in water, the increase in potential due to bubbling is bound

to be much less significant than that on acidification of the solution with liberation of *HOCl*.

Mallmann and Ardrey (13) studied the oxidation potential and germicidal efficiency of hypochlorite solutions at *pH* 5.0, 7.0, and 9.0, both in the presence and absence of dissolved and suspended organic materials (peptone for the dissolved and agar for the suspended substances) and concluded that the oxidation potential serves as a more accurate measurement of relative germicidal activity between different concentrations of chlorine than does the starch-iodide or ortho-tolidine method. These authors seem to favor the use of oxidation potentials for measuring the germicidal chlorine, but they failed to show how the potential measurements might be interpreted in terms of germicidally active chlorine. A study of the data of Mallmann and Ardrey reveals that the potential of the chlorinated water at similar germicidal levels oftentimes varied considerably in different tests under different conditions. Since these authors used different numbers of organisms in different tests, or even in the same test, it is hard to make a fair comparison of the potentials at fixed germicidal levels. Even with a more or less similar number of organisms, the potential of the treated water at a similar germicidal level differed considerably at different *pH* values. For instance, a sample containing 30,000 *E. coli* per ml of water at *pH* 5.0 showed 99.7% destruction in 3 minutes of contact at a potential of 695 mv (with reference to the saturated *KCl*-calomel half cell), while a sample containing 29,400 *E. Coli* per ml of water at *pH* 7.0 showed 100% destruction within 2 minutes of contact at a potential of 480 mv, and a sample containing 23,800 *E. coli* per ml of water at *pH* 9.0 showed 100% destruction in a ½-minute contact period at a potential of 465 mv.

In the course of the writer's studies on the cysticidal efficiency of different chlorine (and chloramine) compounds in the past few years, he has also attempted to relate his findings to oxidation potential values. A previous paper (7) has already presented some data on potential measurements in connection with the cysticidal activity of calcium hypochlorite, chloramines ($NHCl_2$ and NH_2Cl), and gaseous chlorine. The results obtained indicated that oxidation potential measurements might provide a more accurate yardstick of the cysticidally active chlorine than could be obtained by the acid starch-

iodide or the ortho-tolidine method, because the oxidation potential seemed to indicate in a chlorine solution the amount of active chlorine irrespective of the *pH* and amount of organic material present. The potentials of the hypochlorite and gaseous chlorine solutions recorded at cysticidal levels were quite different from those of solutions of chloramines ($NHCl_2$ and NH_2Cl). In more recent tests, although results similar to those previously presented were obtained with tap water, irregular results were frequently noted for raw waters, even when the ammonia-nitrogen content was negligible. Potential measurements were also made for solutions of Halazone, Dactin, succinchlorimide, and chloramine-T. To illustrate the relationship between oxidation-reduction-potentials and cysticidal concentrations of various chlorine and chloramine and chlorimide compounds, the pertinent data are summarized in Tables 1 and 2.

The materials used and procedures adopted in these tests have been described in an earlier paper (7). The *pH* was measured with a glass electrode connected to a potentiometer. The potentials were determined with a brilliant platinum wire against a saturated *KCl*-calomel half-cell connected to a Coleman electropotentiometer. The measurements are expressed here as E_h in millivolts, the values of E_h having been obtained by correcting the observed potentials with reference to the normal hydrogen electrode. The potentiometer and electrode vessels were arranged as shown in Figure 3 so that five determinations could be made practically simultaneously by changing the switchboard connections. During the measurements, especially with chloramines, a steady drift of the potential was noticed and a period of 15 to 60 minutes elapsed before equilibrium was reached, but about 90 per cent or more of the potential was reached in 10 to 15 minutes. Readings were taken either at, or close to, the point of equilibrium. The platinum wire was heated to redness in a flame after each measurement; when this was not done, erroneous readings were obtained, especially with water containing fine suspended particles of organic substances.

Table 1 shows for relatively pure water containing an insignifi-

TABLE 1.—RELATION OF OXIDATION POTENTIAL TO CYSTICIDAL EFFICIENCY OF GASEOUS CHLORINE AND CALCIUM HYPOCHLORITE IN TAP WATER, RAW WATER, AND TAP WATER CONTAINING 0.02% PROTEOSE-PEPTONE.

Type of Chlorine Compound	Temperature °C	Contact Period in min.	Minimal Cysticidal Residual Chlorine in p.p.m. at Varying *pH* Values Chlorine	*pH*	Caculated Amount of HOCl in p.p.m.	Value of E_h in Millivolts
Calcium Hypochlorite (1) in Tap Water	18	15	From 3.27 to 12.75	at 7.0 to 8.5	1.53 to 2.09	970 to 1,000
	18	30	From 2.16 to 8.73	at 6.9 to 8.5	1.05 to 1.41	910 to 940
	18	60	From 1.24 to 4.90	at 7.0 to 8.5	0.71 to 0.93	860 to 890
	18	120	From 0.80 to 4.00	at 7.0 to 8.5	0.54 to 0.58	790 to 810
	18	10	From 3.40 to 49.00	at 5.15 to 8.8	2.95 to 3.22	971 to 1,030
	23	10	From 19.80 to 38.90	at 8.5 to 8.9	1.88 to 2.38	930 to 938
	28	10	From 7.90 to 42.10	at 8.1 to 8.9	1.29 to 2.06	910 to 930
(2) in Charles River Water*	23	10	From 3.50 to 5.70	at 6.5 to 7.4	——	827 to 872
	25	10	From 2.40 to 4.20	at 5.1 to 7.4	——	796 to 866
	28	10	From 3.50 to 4.10	at 6.7 to 7.2	——	770 to 799
Gaseous Chlorine in 0.1% Sewage**	18	30	From 1.40 to 1.80	at 6.8 to 7.0	1.06 to 1.40	900 to 950
	18	60	From 1.00 to 1.30	at 6.8 to 7.1	0.76 to 0.95	840 to 870
	18	120	From 0.80 to 0.90	at 6.8 to 7.1	0.63 to 0.65	790 to 810
Gaseous Chlorine in 0.02% Peptone†	18	30	23.4 to 25.2	at 3.4-3.6	——‡	929 to 938
	18	60	18.2 to 20.8	at 3.6-4.1	——	917 to 930
	18	120	15.1 to 18.2	at 3.7-4.5	——	892 to 905

*Charles River water contained 2 to 3.5 p.p.m of total organic nitrogen and a trace of ammonia nitrogen. The *pH* of the water was regulated to 5.0, 6.0 and 7.0 with citric acid before it was dosed with hypochlorite. The chlorine demand at the stated temperature, *pH*, and contact period was about 5 to 7 p.p.m.

**The amount of ammonia and organic nitrogen was so small that the influence of chloramines was neglected.

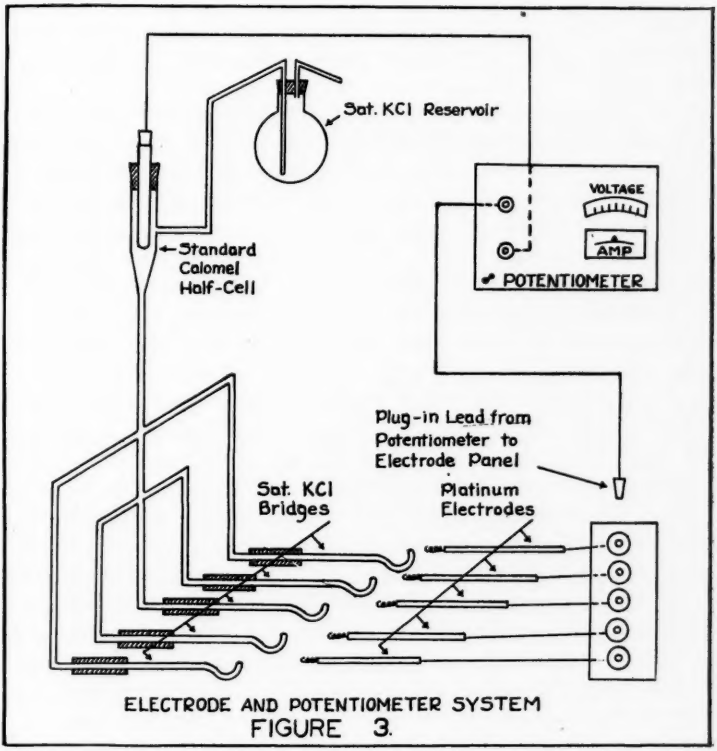
†The proteose-peptone solution was prepared in tap water and had a total organic nitrogen content of 25 to 32 p.p.m.

‡The amounts of *HOCl* are not calculated because of the formation of organic chloramines.

TABLE 2.—RELATION OF OXIDATION POTENTIAL TO CYSTICIDAL ACTIVITY OF AMMONIA-CHLORAMINES, HALAZONE, SUCCINCHLORIMIDE, DACTIN AND MONOCHLORAMINE-T IN TAP WATER AND RAW WATER

Type of Chloramines	Temp °C	Contact Period in min.	Minimal Cysticidal Residual Chlorine in p.p.m. Chlorine	*pH*	Value of E_h in Millivolts
Ammonia-Chloramines[1]	18	15	4.4 to 5.0	at 6.9	790 to 798
	18	30	2.5 to 3.0	at 7.0	750 to 759
	18	60	1.6 to 1.9	at 7.1	692 to 706
	18	120	1.0 to 1.4	at 7.2	653 to 670
Ammonia-Chloramines[2]	18	15	4.5 to 4.9	at 6.9	758 to 769
	18	30	2.7 to 2.9	at 7.0	738 to 749
	18	60	1.9 to 2.1	at 7.1	705 to 718
	18	120	1.2 to 1.5	at 7.2	664 to 694
Ammonia-Chloramines[3]	18	15	11.4	at 8.6 to 8.9	650 to 658
	18	30	6.8	at 8.6 to 8.8	620 to 630
	18	60	5.0	at 8.6 to 8.8	600 to 614
	18	120	4.0	at 8.6 to 8.8	596 to 614
Halazone in tap Water[4]	18	10	10.9 to 11.7	at 5.5 to 7.0	1,034 to 1,088
	23	10	10.9 to 13.9	at 5.7 to 7.4	1,028 to 1,068
	23	15	11.4 to 11.7	at 7.4 to 8.0	713 to 1,028
	23	30	5.7 to 6.0	at 7.4 to 8.5	680 to 998
	23	60	5.7	at 7.5	998
Halazone in Charles River Water[5]	23	10	10.9	at 7.0	848
	23	30	7.3	at 7.3	558
	25	30	7.0	at 7.3	641
	26	30	8.0 to 9.4	at 7.3	590 to 626
Succinchlorimide in Tap Water[6]	23	10	82.4 to 85.2	at 4.5 to 5.0	1,091 to 1,106
	23	20	80.5 to 83.0	at 5.0 to 5.5	1,086 to 1,094
Monochloramine-T in Tap Water	23	20	136.0	at 7.2	820
Dactin in Tap Water[7]	23	10	17.3	at 6.7	974

[1]Chloramines prepared from NH_4Cl and gaseous chlorine in a ratio of NH_3:Cl_2 = 1:4 in tap water.
[2]Gaseous chlorine added to tap water containing 10% sewage and NH_3 in concentrations from ½ to ¼ of those of chlorine.
[3]Chloramines prepared from NH_4OH and gaseous chlorine in a ratio of NH_3:Cl_2 = 1:4 in tap water.
[4]Tablets of Halazone used in tap water regulated at *pH* 4.0, 5.0, 6.0 and 7.0 with citric acid.
[5]Charles River water contained 2 to 3.5 p.p.m. of total organic nitrogen and a trace of ammonia-nitrogen. It had a chlorine demand at the stated temperatures and contact periods of 6 to 7 p.p.m.
[6]Tablets were used.
[7]Dactin . . . 1, 3 dichloro 5, 5 dimethyl hydantoin.



ELECTRODE AND POTENTIOMETER SYSTEM
FIGURE 3.

cant amount of organic and ammonia nitrogen that both gaseous chlorine and calcium hypochlorite were cysticidal at quite similar and fairly consistent oxidation potentials for particular contact periods and at particular temperatures. The amount of *HOCl* calculated from the value of K_d for each cysticidal amount of residual chlorine was also fairly constant. Therefore, it appears that the oxidation potentials of the chlorine-treated water reflect the concentrations of *HOCl*.

This consistency of potential readings however, was not observed for Charles River water in which differences of as much as 125 mv were recorded at cysticidal concentrations of chlorine. Also, the cysticidal potential readings for Charles River water were about 60 to 100 mv lower than those observed for tap water. Since Charles River water contained only a trace of ammonia-nitrogen, the possibility of formation of chloramines can be eliminated. It is believed that suspended fine particles of organic matter might have been adsorbed on the platinum wire and so might have changed its electrode characteristics.

The cysticidal amounts of residual chlorine in 0.02% proteose-peptone water were extremely high for all contact periods as compared with those determined for tap water. If we assume that all the residual chlorine was present as *HOCl*, the amount of *HOCl* would be about 20 times as great as that required for tap water. Here the potential readings, if they reflected the amount of *HOCl*, indicated that the actual amount of *HOCl* in the peptone water was not much, if any, more than that in tap water at cysticidal concentrations of chlorine, since the potential readings of the former were about the same as for 30 minutes of contact in tap water, and only slightly higher for 60 and 120 minutes of contact. Hence it is apparent that most of the residual chlorine in the peptone water probably combined with the amino acids to form relatively inactive chloramines of low oxidation-reduction potentials and only a small amount of the chlorine existed as *HOCl* to effect the destruction of cysts.

The oxidation potentials of the chloramines ($NHCl_2$ and NH_2Cl) at cysticidal concentrations were also consistent for each contact period, but they were considerably lower than those for gaseous chlorine and hypochlorite, in spite of the fact that the residual titrat-

able chlorine was higher. This indicates that chloramines possess an entirely different oxidation potential than do the chlorine compounds and that potential readings for cysticidal values of chlorine compounds cannot be applied to solutions of chloramines.

The cysticidal potentials of Halazone in tap water were in most cases about 60 to 100 mv higher than those for gaseous chlorine and hypochlorite, and were inconsistent on some occasions in that differences of as much as 300 mv were sometimes recorded at cysticidal concentrations. The potentials of Halazone in raw waters at cysticidal values were even more inconsistent and were from 40 to 300 mv lower than those in tap water.

The cysticidal potential of succinchlorimide-treated tap water was the highest among these chlorine, chloramine and chlorimide compounds. Usually, an E_h of about 1,100 mv was registered at cysticidal concentrations, no significant difference being noted between contact periods of 10 and 20 minutes. The cysticidal potential readings were higher by 100 mv or more for succinchlorimide than for gaseous chlorine and hypochlorite. In comparing the oxidation potentials of Halazone and succinchlorimide at cysticidal levels, it is revealed that Halazone, in general, shows a potential reading close to that of succinchorimide at concentrations at which the residual chlorine from the former is only about one-third that of the latter. As pointed out before (6), this is probably due to the fact that Halazone, being a di-chlor compound, hydrolyses considerably with release of *HOCl,* while on the other hand, succinchlorimide, being a mono-chlor compound, shows no significant amount of hydrolysis in water and remains a chlorimide, even at a *pH* of 2.0 and for a period of 4 hours.

Among the chlorine, chloramine and chlorimide compounds studied, monochloramine-T was the least cysticidal. Its oxidation potential at cysticidal concentrations, though very low for such a high residual, was slightly higher than that of chloramines.

In view of these observed facts, it is apparent that the chlorine compounds and each of the chloramine compounds have their own characteristic oxidation potentials, and that the oxidation potential for one compound at observed cysticidal concentrations gives no information on the cysticidal efficiency of any other compound. This destroys the overall value of oxidation potential measurements as

parameters of the cysticidal or germicidal properties of chlorine compounds. Thus the practicability of potential measurements becomes confined to solutions in which the nature of the compound that exerts the killing activity is known. When more than one chlorinating agent is called into existence, as when chlorine is added to water containing some ammonia nitrogen and part of the chlorine is converted to chloramines, interpretation of the potential readings in terms of killing activity becomes almost impossible. Furthermore, the inconsistent and lower oxidation potentials obtained in raw waters, as compared with those in tap water, render the interpretation of potential measurements of very little value for such water.

Electrochemistry of Solutions of Chlorine, Chloramine, and Chlorimide Compounds in Water

In order to see if oxidation-reduction potentials could be interpreted in terms of amounts of germicidally-active chlorine the electrochemistry of solutions of these compounds was studied. So complicated are the oxidation-reduction systems in a solution of chlorine, chloramine, or chlorimide compounds, and so incomplete is our knowledge of the electrochemical activities of these systems, that any approach that one can make to this subject is bound to be incomplete and open to criticism. Up to the present time, no evidence has been presented that the chloramine- or chlorimide-chloride reaction is reversible. In a solution of succinchlorimide, the writer is certain that the reaction is not reversible. He has constantly observed a steady drop of the potential, a decrease in titratable chlorine, and a lowering of the *pH* value. While no attempt was made to find out the actual changes taking place, it is believed that decomposition of succinchlorimide with formation of chloride occurred progressively in the solution. With di-chloramine compounds, the chloramine-chloride reaction is further complicated by the hydrolysis of the chlorine with formation of *HOCl*.

Considering a solution of gaseous chlorine or calcium hypochlorite, it should be possible to derive the oxidation potential registered on a potentiometer from one of the following three systems or from combinations of them:

$$\tfrac{1}{2}Cl_2 + e \rightleftharpoons Cl^- \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad E^\circ = 1.358 \text{ volt at } 25\ ^\circ C \quad (5)$$

$$HOCl + H^+ + 2e \rightleftharpoons Cl^- + H_2O \quad \ldots\ldots \quad E^\circ = 1.500 \text{ volt at } 25\ ^\circ C \quad (6)$$

$$OCl^- + H_2O + 2e \rightleftharpoons Cl^- + 2OH^- \quad \ldots \quad E^\circ = 0.940 \text{ volt at } 25\ ^\circ C \quad (7)$$

The standard oxidation potential values E° of these electrodes are taken from Latimer and Hildebrand's "Reference Book of Inorganic Chemistry" (14). Theoretically, the value of the oxidation potential of a chlorine solution calculated from any of these three reactions should be the same as that calculated from any other when equilibrium is reached; but the complexity of the reactions involved makes the calculation extremely difficult. On this account, Glasstone (15) has suggested the introduction of an acid before measuring the oxidation potential so that only Reaction (5) will occur. However, in dilute solutions of chlorine, this is not true. As shown in Figure 1, even in a solution of gaseous chlorine containing 71 p.p.m. of titratable chlorine at *pH* 0.0, or 710 p.p.m. of titratable chlorine at *pH* 1.0, only about one-half of the total chlorine exists as Cl_2 and the other half as *HOCl*. Furthermore, in the process of chlorinating water, we are interested in the relative amounts of Cl_2, *HOCl*, and OCl^- present.

In order to illustrate the complexity of the reactions in a chlorine solution, the pertinent data obtained by the writer are presented and discussed in the following paragraphs:

Effect of Increasing Concentration of Titratable Chlorine on the Oxidation Potential of a Chlorine Solution. The results of tests with gaseous chlorine and calcium hypochlorite (commercial product) at *pH* 3.0, 6.5, and 6.7 are summarized in Table 3 and Figure 4. It is seen that, for gaseous chlorine, the relationship between oxidation potential and chlorine concentration at *pH* 3.0 follows a straight line from about 480 p.p.m. down to 10 p.p.m. of titratable chlorine. Below 10 p.p.m., however, the slope of the line through the points seems to change progressively. The potentials were measured several hours after the solution was prepared; presumably at equilibrium, therefore. At the chosen *pH* values and concentrations of titratable chlorine, the amount of chlorine existing as Cl_2 is so small (see Figure 1) that it may be ignored. The oxidation potential appears to be directly proportional to the logarithm of the concentration of *HOCl* above 10 p.p.m. of titratable chlorine. The change

TABLE 3.—EFFECT OF INCREASE IN CONCENTRATION OF *HOCl* ON THE OXIDATION POTENTIAL OF A SOLUTION OF GASEOUS OR CALCIUM HYPOCHLORITE AT 22.5 TO 23.0 °C*

Type of Chlorine Compound	Final *pH* of the Solution**	Residual Chlorine in p.p.m†	Log of Residual Chlorine	Value of E_h in Millivolts‡
Gaseous Chlorine	6.3±.1	0.18	—.745	737
	"	0.36	—.444	812
	"	0.54	—.268	854
	"	0.70	—.155	889
	"	0.86	—.066	909
	"	1.04	0.017	935
	"	1.28	0.107	953
	"	1.34	0.127	963
	"	1.64	0.214	973
	"	1.82	0.260	989
	"	2.78	0.444	1,028
	"	3.67	0.564	1,049
	"	6.50	0.812	1,075
	"	10.25	1.010	1,093
	"	15.90	1.201	1,107
	"	30.20	1,480	1,128
	"	41.70	1.620	1,145
	3.0±.1	0.65	—.188	1,093
	"	2.00	0.301	1,155
	"	3.90	0.591	1,254
	"	9.80	0.990	1,291
	"	39.80	1.600	1,329
	"	112.10	2.049	1,360
	"	199.50	2.300	1,371
	"	373.10	2.571	1,388
	"	478.50	2.679	1,393
Calcium Hypochlorite	6.7±.1	0.36	—.444	817
	"	0.80	—.073	922
	"	1.70	0.230	995
	"	2.53	0.403	1,042
	"	3.60	0.556	1,062
	"	4.58	0.658	1,080
	"	5.50	0.740	1,088
	"	6.55	0.816	1,100
	"	7.60	0.880	1,105
	"	8.50	0.929	1,110
	"	9.60	0.982	1,114
	"	10.28	1.028	1,120

*Tabulated results are averages of 2 or 3 tests.

**To avoid change of chloride concentration, the *pH* was regulated with 0.1 *N* H_2SO_4 and 0.1 N *NAOH* solutions.

†Residual chlorine was determined by acid starch-iodide. The standard deviation varied from ±0.05 to ±0.2.

‡The potential readings had a standard deviation of from ±1.2 to ±3.2 mv.

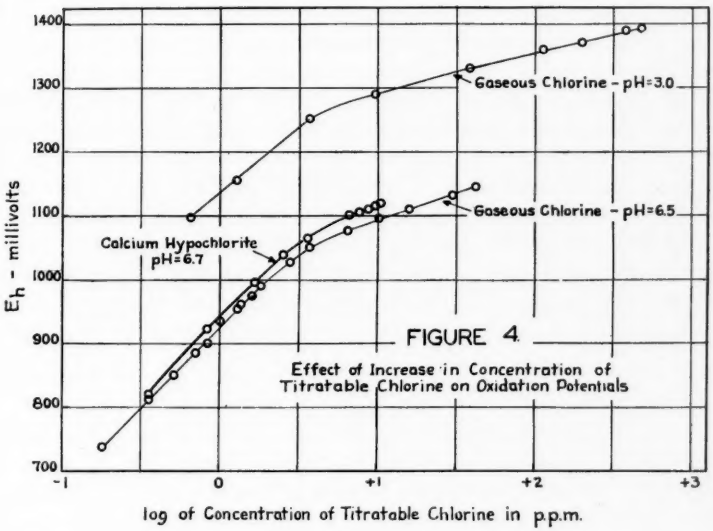


FIGURE 4.

Effect of Increase in Concentration of Titratable Chlorine on Oxidation Potentials

TABLE. 4.—EFFECT OF *pH* ON THE OXIDATION POTENTIAL OF A SOLUTION OF GASEOUS CHLORINE CONTAINING 10 P.P.M. OF TITRATABLE CHLORINE AT 22.8 °C

pH of the Solution	E_h in mv
1.08	1,390
2.15	1,336
3.20	1,275
3.96	1,239
5.11	1,165
6.20	1,084
7.15	1,012
8.30	909
9.18	810
10.10	698
11.00	556

in slope below 10 p.p.m. is probably due to a decrease in sensitivity of the platinum electrode at such dilutions. This clearly shows that the theoretical potential values calculated from Reaction (6) by

using the dissociation constant of *HOCl* would be quite different from those observed for these very dilute solutions.

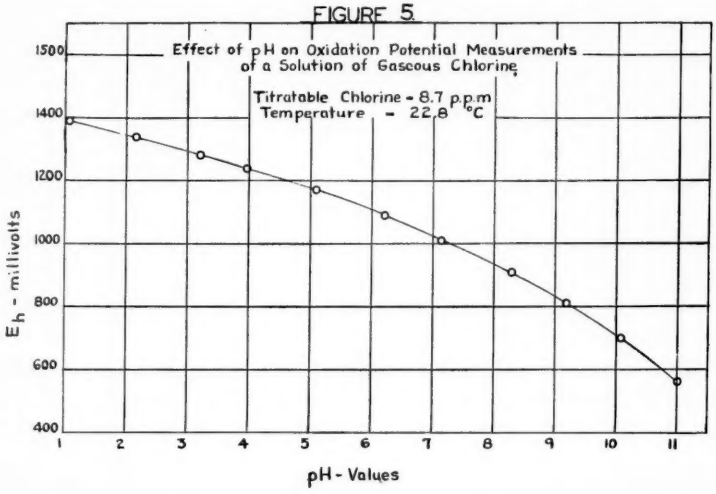
Effect of pH on the Oxidation Potentials of a Gaseous Chlorine Solution. The relationship between the *pH* and oxidation potential of a chlorine solution is illustrated in Table 4 and Figure 5. Between *pH* 1.0 and 5.0, the points seem to follow a straight line with an approximate slope of 59 mv. Between *pH* 5.0 and 11.0 on the other hand, the potentials drop at an accelerated rate as the *pH* increases. While this progressive drop in the potentials above *pH* 5.0 can be explained in terms of the increasing dissociation of the *HOCl* with increasing amounts of OCl^- formed, the slope of 59 mv below *pH* 5.0 is not readily understandable. The potential equation of *HOCl* is

$$E = E^\circ - \frac{RT}{nF} ln \frac{(HOCl)(H^+)}{(Cl^-)} \qquad (8)$$

where E is the potential of the *HOCl* solution, E° is the standard potential of Reaction (6), R is the gas constant, T is the absolute temperature, n is the number of electrons involved, and F is one Faraday. Equation (8) shows that if Reaction (6) is reversible, then the equation may be expressed as

$$E = E^\circ - \frac{0.059}{2} log\ (H^+) \qquad (9)$$

FIGURE 5



Therefore, the observed slope below *pH* 5.0 is twice the theoretical. As the data are too consistent to be accidental, the phenomenon is not explained.

Effect of Chloride Ion Concentrations. The effect of chloride ion concentrations on the oxidation potential of *HOCl* is shown in Table 5.

TABLE 5.—EFFECT OF CHLORIDE-ION CONCENTRATION ON OXIDATION POTENTIAL OF A SOLUTION OF GASEOUS CHLORINE AT *pH* 3.8 AND 23 °C AND CONTAINING 24 P.P.M. OF TITRATABLE CHLORINE

Amount of NaCl added, in p.p.m.	E_h in mv	Final *pH*	E_h corected to *pH* 3.8
100	1,297	3.8	1,297
300	1,301	3.8	1,301
500	1,312	3.75	1,309
900	1,320	3.71	1,314
1,500	1,329	3.66	1,320

Again, if Reaction (6) is reversible, the oxidation potential of the *HOCl* solution should undergo a steady decrease with steady increase in chloride ion concentration. Instead a slight but steady increase in the potential readings was recorded. This same phenomenon is evident also in Figure 4 in which the solution of calcium hypochlorite at *pH* 6.7 gave potential readings that were 5 to 25 mv higher than those for gaseous chlorine at *pH* 6.5, the former solution having a chloride ion concentration over 10 times greater than that of the latter. What this indicates is not understood.

In addition, the complex nature of the oxidation potential of chlorine solutions is further affected by the presence of dissolved oxygen. Any amount of dissolved oxygen will exert a potential according to the following equations:

$$\tfrac{1}{2}O_2 + H_2O + 2e^- \rightleftharpoons 2OH^- \tag{10}$$

$$E = E^\circ - \frac{RT}{nF} \ln \frac{(O_2)^{\frac{1}{2}}}{(OH^-)^2} \tag{11}$$

At a pressure of 1 atmosphere, the activity of O_2 gas is taken as unity, and

$$E = E^\circ \frac{RT}{nF} \ln \frac{1}{(OH^-)^2} \tag{12}$$

$$E = E^{\circ} - 0.059 \log \frac{1}{(OH^{-})} \qquad (13)$$

Since (OH^{-}) may be replaced by k_w/H^{-}, where k_w is the ionic product of water, and since the E°, under practical conditions, is not the same as E° in Equation (12), it follows that

$$E = E^{\circ\prime} - 0.059 \log (H^{-}) \qquad (14)$$

where $E^{\circ\prime}$ designates the E° under operating conditions. In spite of the fact that the oxygen electrode is not reversible, especially when a bright platinum wire is used the oxygen electrode has been used for *pH* determinations. Even the air electrode has been found to give fairly accurate *pH* measurements. At a fixed *pH*, the potential of the oxygen electrode varies with the amount of dissolved oxygen, although the potential changes do not follow the theoretical values. To illustrate these points, the potential readings obtained for distilled, tap, and raw waters containing known amounts of dissolved oxygen were determined at varying *pH* values. They are shown in Table 6. The data pertaining to the relationship between oxidation potential and *pH* in distilled and tap water are shown in Figure 6.

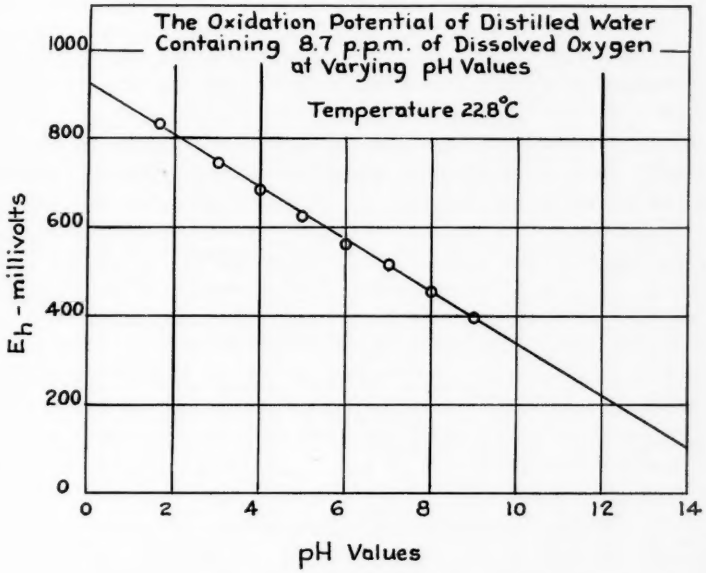
TABLE 6.—OXIDATION POTENTIALS OF DISTILLED, TAP, AND RAW WATERS AT VARYING *pH* VALUES

Type of Water	Amount of Dissolved Oxygen in p.p.m.	*pH*	E_h in mv
Distilled	8.5*	1.62	832
and Tap	"	3.0	746
Water	"	4.0	688
	"	5.0	629
	"	6.0	561
	"	7.0	512
	"	8.0	452
	"	9.0	396
Charles River	4.4	6.9	376
Water**	5.6	6.7	386
	6.4	6.8	389
	7.1	6.8	398

*The distilled water and tap water were aerated before use. The amount of dissolved oxygen varied in different tests within a standard deviation of ±0.3 p.p.m.

**Charles River water had a total organic nitrogen content of 2 to 3.5 p.p.m. Determinations were made without aeration.

FIGURE 6



In a *pH* range of 1.6 to 9.0 the relationship between oxidation potential and *pH* is closely represented by Equation (14). The potential readings for Charles River water, having a dissolved oxygen content between 50 and 90 per cent of saturation, were uniformly lower, but much lower than could be accounted for by the smaller amount of dissolved oxygen. The presence of other oxidation-reduction systems in raw waters and the inactivation of the platinum wire by absorption of organic particles may well be responsible for this phenomenon.

On the whole, it may be said that although potential measurements for relatively pure water treated with chlorine seem to reflect the amount of *HOCl*, the complex oxidation-reduction systems in the chlorinated water, the uncertainty of the reversibility of these systems, and the presence of the oxygen electrode make the interpretation of oxidation potentials in terms of active chlorine extremely

difficult. The presence of other interfering substances and the uncertain amount of dissolved oxygen in raw waters render the evaluation of potential measurements almost impossible. The interpretation of potential measurements for chloramine or chlorimide compounds is even more difficult than that for chlorine compounds in view of the facts that each compound has its own characteristic potential and that the oxidation-reduction reaction is probably non-reversible. It is felt, therefore, that unless an electrode can be developed that is selective for the chlorine-chloride reaction, the measurement of oxidation potentials as evaluating germicidally active chlorine is of practical value only in limited and specified circumstances and when the nature of the compound used is known.

Summary and Conclusions

The validity of employing oxidation potential measurements for chlorinated waters for the evaluation of germicidally active chlorine has been studied both from the cysticidal and the electrochemical points of view. As a result of this study, the following conclusions have been reached:

1. Although consistent and characteristic potentials were frequently observed at the cysticidal point for gaseous chlorine and calcium hypochlorite, chloramines ($NHCl_2$, NH_2Cl), Halazone, and succinchlorimide in tap water, irregular potentials and potentials lower than those in tap water were usually obtained in raw waters.

2. Evaluation of the significance of the oxidation potential of a chlorinated water was not attempted in view of the complicated oxidation-reduction systems that exist in such a water, the uncertainty of the reversibility of these systems, and the presence of dissolved oxygen.

3. Chlorine compounds and each of the chloramine and chlorimide compounds had their characteristic potentials at cysticidal concentrations, and the cysticidal potential for one compound carried no implication as to the cysticidal efficiency of any other compound.

The technical assistance of Mrs. Margery P. Taylor and Miss Margaret Alexander was most helpful.

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PROCEEDINGS

November 1944 Meeting

Hotel Statler, Boston, Mass.

Thursday, November 16, 1944

President Karl R. Kennison in the Chair.

Secretary Gifford reported the death of three members:

Hugh McLean, Holyoke, Mass.; died June 1, 1944.

Charles D. Howard, Director of Sanitary Engineering, New Hampshire State Board of Health; died October 29, 1944.

Edward F. Hughes, Sr., Watertown, Mass.; died November 14, 1944.

Secretary Gifford announced the election of the following new members:

Harry P. Loftus, Water and Sewage Commissioner, Marlboro, Mass., and Harvey B. Kinnison, District Engineer, U. S. Geological Survey, Melrose, Mass.

The President introduced David E. Moulton, Attorney for the Portland Water District, Portland, Maine, and conferred upon him Honorary Membership in the Association.

A paper "The New England Hurricanes of 1938 and 1944" was read by Lyndon T. Rodgers, District Forecaster, United States Weather Bureau, Boston, Mass.

Papers on "Effect of 1944 Hurricane on Water Supplies" were read by Walter J. Shea, Chief Engineer, Rhode Island Department of Health, and Francis H. Kingsbury, Associate Engineer, Massachusetts Department of Public Health.

A film on water pumping, entitled "Underground Raindrops," was presented through the courtesy of U. S. Electrical Motors, Inc.

A U. S. Army film, "Road to Paris," was also presented.

DECEMBER 1944 MEETING

HOTEL STATLER, BOSTON, MASS.

Thursday, December 21, 1944

President Karl R. Kennison presiding.

In the absence of Secretary Gifford, ARTHUR L. SHAW reported the following elections:

Members: Burnell E. Frisbie, Kittery, Me.; Herman G. Dresser, Wakefield and Boston, Mass.; and William Andrew Healy, Concord, N. H.

Associate Member: Nuken Products Corporation of Buffalo, N. Y., manufacturers of jointing compounds for pipe lines.

A paper "Underwater Photography" was read by Prof. Maurice Ewing, Woods Hole Oceanographic Institution. Some of the underwater pictures were shown by lantern slides.

A moving picture film, "Design and Construction of a Water Collection and Transmission System," was shown through the courtesy of the Johns-Manville Corporation, New York, N. Y.

Some U. S. Army films were also shown.

JANUARY 1945 MEETING

HOTEL STATLER, BOSTON, MASS.

Thursday, January 11, 1945

President Karl R. Kennison in the chair.

In the absence of the Secretary, ARTHUR L. SHAW announced the election of the following:

Member: Carl E. Chapan, Acting Superintendent, Public Works Department, Saugus, Mass.

Associates: Edward F. Hughes, artesian, driven and gravel packed wells and test borings, Belmont, Mass.; and Northrop & Company, Inc., manufacturers of jointing compounds, and distributors of water works specialties and supplies, New York, N. Y.

Mr. Shaw reported the death on December 30, 1944, of George A. Caldwell, Associate.

A paper "The Place of Public Works Construction in Post-War Planning," was read by Willard F. Rockwell, President, Pittsburgh Equitable Meter Company, and former member Army and Navy Munitions Board and War Production Board.

A talk and demonstration of the Permutit Sea Water Desalting Kit was given by Eskel Nordell, Technical Engineer, the Permutit Company, New York, N. Y.

A sound film, "Rhapsody in Speed," in technicolor, was presented through the courtesy of U. S. Electrical Motors, Inc.

Some U. S. Army films were also shown.

COMMITTEE ON WATER AND SEWAGE WORKS DEVELOPMENT

SECRETARY'S REPORT*

November 30, 1944

During the Milwaukee Conference of the American Water Works Association, the members of this Committee held duly-called meetings to consider the work which had been done by the Committee and to decide upon any future activities which might appear to be indicated. At the conclusion of the second session of the Committee the following general resolution was adopted:

RESOLVED, That this Committee should continue through June 30, 1945, with the following objectives and procedures:

1, to continue to promote, where needed, construction of water works and sewage works and the appurtenances thereto as a definite part of postwar planning in every community in the United States and Canada;

2, to do this through the continuance of a central office with a full-time campaign manager and the continued mailing of promotional literature, preferably of the specific example-type and coöperation of advertisers in the trade and promotional press;

3, to continue coöperation with the state sanitary engineers and after conference with such engineers to undertake in each state that type of cooperation which seems to be indicated and approved by this Committee;

4, to do this to the extent of the remaining funds pledged by the Association embraced in this Committee and in an additional appropriation of funds up to $10,000.00 made to this Committee today by the Water and Sewage Works Manufacturers Association.

5, if the continuance of the central headquarters at the head office of the American Water Works Association places too great a load upon that office and its personnel, Mr. Jordan should arrange with Mr. Clark of the Water and Sewage Works Manufacturers Association for the transfer of such central office facilities to the office of the Water and Sewage Works Manufacturers Association.

Another meeting of the Committee was held on July 13, 1944 and

*Accepted by the Executive Committee of the New England Water Works Association on January 11, 1945.

there was discussed at that time the precise steps to be taken to put into effect the items of the June 15th resolution. After an extended review of the situation there issued on August 31, 1944 an outline of the 1944-5 program of the Committee on Water and Sewage Works Development. This outline was then sent to the members of the Committee and other officials of the constituent associations. No objections were filed. The employment of a full time campaign manager which was implied in the second paragraph of the resolution of June 15th, will not be undertaken. The work will be carried on by the presently employed staffs of the Water and Sewage Works Manufacturers Association and the American Water Works Association. The 1944-5 program sets up the principal activity of the Committee to mid-year 1945 to be the production and circulation of a bulletin *Blueprint Now in Action*. This bulletin is intended to be built about case histories of actual planning that has been done for various communities. The second bulletin has been issued.

The policy and objectives of the Committee on Water and Sewage Works Development are expressed in the following paragraphs.

1. The Basic Objective of the Committee on Water and Sewage Works Development is reaffirmed—to promote among water and sewage works executives—and the municipal administrators responsible for public works planning, the full realization of the value to the community of *Blueprinting Now* all needed water and sewage works construction to be done as soon as wartime restrictions are lifted.

2. The Committee will continue its policy of being a morale building agency, but not a selling agency. It considers its function to be the development of an aggressive attitude among water and sewage works executives which will lead them in their own service areas, to promote and plan useful water and sewage works construction. It does not consider that its function is to engage in the promotion or development of specific projects. To whatever extent the local executive needs aid of this character, it can be obtained through the activities of the consulting engineer on the one hand and the sales forces of water and sewage works manufacturers on the other.

3. The Committee will not engage in the collection of statistics as such. It recognizes the interest of already existing long term agen-

cies in the collection of data related to construction and planning. Persons having need for organized statistics concerning planned construction in the water and sewage works field should obtain their information from such agencies.

4. The Committee in its initial statement of policy and objectives, issued August 15, 1943 said:

> "We do not believe that we have to wait for federal aid, either for the planning or for the execution of useful public works. The federal aid policy of the Thirties was a major contribution toward the nation's recovery from a serious economic depression and did much to bring water and sewage works to communities whose depression-period need for them was great and whose ability to fund them was lacking. But the conditions of the immediate Forties differ in many ways—in particular because of the fact that both municipal construction and maintenance have deliberately been substantially deferred during the war period while national income has grown to heights never before attained. Thus we can but feel that waiting for federal aid, either in planning or in execution of any public works, can only breed the necessity of having it; while the forthright local progress in planning as well as execution of public works, under the conditions and with the freedom in which American cities for generations carried on such work, will restore the true responsibility that every city and region has for putting its affairs in order and its public works program into effect. We perceive no substantial evidence that American cities need federal aid to put their water works and sewerage programs into action, but rather that the weight of evidence is to contrary."

5. Since this statement was issued, it has become evident that the laws in many states which prohibit the incurring of planning expenses until cash to pay for construction is in hand, makes it necessary that the incentive of loans or grants for planning expense be made effective. This has been done to greater or less degree by state legislation in California, Maryland, Michigan, New Jersey and New York and is contemplated (but funds not yet authorized) through federal loans by the terms of the Reconversion Act.

6. The Committee recognizes the merit of federal loans of reasonable magnitude to municipalities in order to permit them to develop plans for postwar public works and recommends that, if such loans become available and will make it possible for a community to plan public works which could not otherwise be planned, they should be negotiated.

7. The Committee however still holds the opinion that needed water and sewage works construction, *during the immediate post war period can* be financed by the great majority of cities, towns and districts which have need for them. It does not doubt that there are exceptions to this rule, but it does not accept the idea that the inability of a minority of cities should be the basis of grants-in-aid for other than such minority, and then should be based on proof of valid justification.

8. At the end of 1944, the evidence is clear that as soon as wartime restrictions are lifted, the demand for consumer goods, housing and the like will rise to great proportions. This will automatically encourage rehabilitation of water and sewage works facilities as well as additions to existing works to serve new housing and industry. But, there is danger that the desire to provide immediate postwar employment will lead some to overlook this great demand for consumer goods and to promote a program of federal grants-in-aid which will collide in timing with the great demand for consumer goods and services.

9. To superimpose a program of federally aided public works upon the spontaneous demand for consumer goods and the capital investments related thereto is to plan the road to a depression of greater severity than any previous one experienced in America. This is a time for realistic thinking and realistic thinking will not force a depression by premature timing of federal aid.

10. If, after the peace has come, the natural course of enterprise does not maintain a level of adequate employment and it becomes a matter of national policy for the federal government to engage in subsidization of public works, then this Committee agrees that water works and sewage works have such immediate and permanent values in the scale of living that they should commend themselves to those in authority as enterprises to which the federal government can properly give support and aid.

Appraisal of Committee's Work

Work of the character undertaken by this Committee does not lend itself to a definite appraisal of the results obtained. There is substantial evidence that the Committee on Water and Sewage Works

Development has been responsible for a measurable acceleration of planning within its field of interest, in brief—construction. Studies of public works construction in the United States over the past 20 years show that public water supply has accounted for about 2.6% of the total and sewage works construction about 4% of the total. At the end of August, 1944 construction plans underway on water works amounted to 6.5% of the national total, and sewerage slightly over 11% of the national public works program. This substantial plus deviation from the normal probability of the rate of water and sewage works construction cannot be an accident. Water and sewage work construction has had to compete with all of the other forms of public works construction promoted by their own categories of interest. The progress made in the water and sewage works field, therefore appears to be properly regarded as an achievement of the Committee on Water and Sewage Works Development.

Nevertheless, all types of public works planning in the United States, including water and sewage works planning, have been retarded by the rumors concerning federal aid for planning or for construction. As indicated elsewhere in this report, the Committee has firmly held the opinion that water and sewage works construction is a local responsibility, and water and sewage works executives and their city administrators should not anticipate or request federal aid for this class of work. It is to be regretted that representatives of certain federal agencies have been reported as advising municipal executives to make no expenditures on account of planning, nor commitments on account of construction, until "the federal aid" program is set up. This has interfered with planning progress in water and sewage works in certain states.

Federal Loans for Planning

The situation has been actually further complicated by the introduction into the War Mobilization and Reconversion Act of a Section which authorizes the advancement of federal funds for planning public works construction. The related Section of the Act reads as follows:

> "Sec. 501 (a) In order to encourage States and other non-Federal public agencies to make advance provision for the construction of public works (not

including housing), the Federal Works Adminstrator is hereby authorized to make, from funds appropriated for that purpose, loans or advances to the States and their agencies and political subdivisions (hereinafter referred to as 'public agencies') to aid in financing the cost of architectural, engineering, and economic investigations and studies, surveys, designs, plans, working drawings, specifications, procedures, and other action preliminary to the construction of such public works: Provided, that the making of loans or advances hereunder shall not in any way commit the Congress to appropriate funds to undertake any projects so planned."

The difficulty with the passage of this Act, which the President signed with protest on October 3rd, 1944, is that no funds have been provided for the purposes indicated within the particular Section 501.

Not until November 28th was the Congress asked by the President to appropriate $75,900,000 to be distributed by the Federal Works Agencies among states, counties and cities upon a population basis to be spent for plans, specifications, blueprints and engineering services for public works. The President's message pointed out that this amount of money is to be distributed as a loan to the various units of government and restates the previous declaration of Congress that it has assumed no obligation to provide any construction, grants-in-aid to follow the loans for planning.

It is through the recognition of the essential non-dependence of water and sewage services and construction upon the general tax budget that progress can be made toward continued and immediate planning of water and sewage works construction. In so far as the Committee on Water and Sewage Works Development can further that idea, it will continue its promotional activities.

Circumstances Leading to the Organization of the Committee

A resume of the circumstances which led to the organization of the Committee on Water and Sewage Works Development, as well as a record of the activities during its first year follows:

During the year 1942, organization within the water and sewage works field to promote the planning of postwar construction was discussed informally. The first committee to promote postwar planning within these fields was appointed by the New England Water Works Association.

Throughout the first half of 1943 discussions were carried on within the Federation of Sewage Works Associations, the American Water Works Association and the Water and Sewage Works Manufacturers Association looking toward an integration of efforts of all the groups in the producers as well as the consumers field of water and sewage works materials for the purpose of encouraging responsible executives to undertake the design of needed construction which could be carried on immediately after the war was over. Much of the credit for the stimulation of this organization should be given to the development committee of the Water and Sewage Works Manufacturers Association. By mid-year an expression of affirmative attitude from the constituent associations was made and a preliminary meeting of representatives of the four associations was held in Washington on July 16th. Present were Messrs. Becker, Chase, Esty, Emerson, McGinnis, Morris, Schroepfer, Wolman and Jordan. At that time Mr. Abel Wolman agreed to accept the general chairmanship of the Committee on Water and Sewage Works Development and Harry E. Jordan was designated as Secretary. At this meeting a brief statement of objectives of the Committee was developed.

"Believing that adequate water supply and intelligent waste collection and disposal are within the reach of every city, the Committee on Water and Sewage Works Development plans to stimulate the following activities in the cities of North America:

1. An appraisal of the needs for water and sewage works improvement or construction.
2. The development of orderly programs for meeting these needs in an order related to their value to the city or region.
3. The preparation of detailed plans and specifications for the needs of first importance as soon as arrangements can be made.
4. Consideration of, and development of methods for funding the necessary construction.
5. Re-appraisal of authority under which the contemplated projects can be carried on, as well as the legal basis for funding such operations (promotion of legislation whenever needed).
6. Definite scheduling of the construction program (immediate purchase of land and rights of way if part of the projects).

At the same meeting it was agreed that the activities of the Committee would divide themselves into two major categories:

1. A phase of promotional service intended to provide guidance to local officials in promoting acceptance of planning for postwar construction in the water and sewage works field.
2. A field contact through a representative of the Committee whose duties would be to visit with and deal with state, regional and local groups having an interest in water works planning.

A second meeting of the Committee was held in New York on August 9th, 1943. At that time Mr. E. L. Filby of Kansas City was present and discussed with the group the work to be done by a field director. Mr. Filby's services were secured on a leave-of-absence basis from Black & Veatch, consulting engineers in Kansas City, Mo. The Committee was offered, and accepted space for its headquarters at the offices of the American Water Works Association at 500 Fifth Avenue, New York 17, N. Y. There was also discussed at this meeting a preliminary draft of a public statement outlining the Committee's objectives. This statement was issued on August 15th, and was sent to the official boards of the four constituent associations as well as being carried in their respective publications. It was also publicized in the various trade journals throughout the country. Distribution of this release was continued through September and October and approximately 2200 copies were circularized.

It is important to note that the Committee was unanimous in the attitude that planning and especially construction of improvements or additions in the water and sewage works field are the responsibility of local and regional authorities and further that water and sewage works construction or the plans for it should not stand by until federal aid had been made available.

In September, 1943 there was carried on, by letters to the Attorneys General of the 48 states, an investigation to ascertain the status of financing improvements. Replies were received from 40 states and a summary made of the legislation in each state.

Activities of the Field Director

The Field Director made his first trip in September, 1944 to get a preliminary view of the general situation. He attended meetings of the

International City Managers Assn., at Chicago, Ill.

Kansas City Section of the A.S.C.E. at Kansas City, Mo.
Rocky Mountain Section of the A.W.W.A.—Denver, Col.
Kansas Water and Sewage Assn.—Wichita, Kan.
Kansas League of Municipalities—Wichita, Kan.
Western Pennsylvania Section, A.W.W.A.—Pittsburgh, Pa.
New England Water Works Assn.—Boston, Mass.
New York Section, A.W.W.A.—Binghamton, N. Y.

It was apparent that there was a very extensive number of agencies already active in postwar planning in the field of water and sewage works development; e.g., the Interstate Commission on the Delaware River Basin was planning to do for that basin the very same work that was contemplated by this Committee along the lines of sewage treatment. In New York it was found the New York State Planning Commission was beginning to function in the financing of preliminary ad detailed plans for public works improvements including water and sewage.

Brochure—*Blueprint Now for Tomorrow's Needs*

Production was started on the brochure to convey to public officials and responsible officers the *need* for water and sewage works betterments and the necessity of putting these into the blueprint stage immediately for postwar construction. Acknowledgment is made at this point of the most excellent coöperation given the Committee by Johns-Manville, member of the Water and Sewage Works Manufacturers Association, for making available to it for the production of the brochure several of its staff members.

Short check-lists were prepared for the brochure, which could be used by water and sewage works superintendents.

The text for the brochure, *Blueprint Now for Tomorrow's Needs,* was sent to the printer in mid-November, 1943.

In December, 1943, 10,000 copies of *Blueprint Now for Tomorrow's Needs,* were distributed. It was sent to the official boards of the constituent associations, to superintendents of water and/or sewage works in towns of 10,000 population and over in the United States, to State Sanitary Engineers, to Consulting Engineers and to trade journals to advertise its availability without charge to persons who could put it to good use in their communities. Twenty copies

were sent to each member of the Water and Sewage Works Manufacturers Association so that their salesmen might bring it to the attention of the smaller town superintendents who might not be reached by the Committee's mailing list.

The brochure was so enthusiastically received, and requests were so numerous that the first 10,000 copies were exhausted within a month and a second printing of 10,000 copies was ordered. A third printing of 10,000 was ordered the third month. A large part of the third printing was used in a mailing to water superintendents and city engineers in towns of 2,500 to 10,000 population.

Shortly after the brochure was issued, it was found that the check lists had been republished in *Water and Water Engineering*, a British publication. The idea of a check list appeared to have much merit and the original lists were amplified. The amplified water works list was published in the May, 1944 issue of the *Journal of the American Water Works Association* (Vol. 36, No. 5) and the list for sewage works superintendents appeared in the *Sewage Works Journal* for May, 1944 (Vol. XVI, No. 3). Reprints of the Water Works list are available for distribution.

On October 5, 1943 a letter was addressed to the members of the Water and Sewage Works Manufacturers Association and to their advertising agencies. This conveyed a copy of the brochure and called attention to the propriety of including the Committee's slogan in their advertising programs. This appeal, plus the requests made by the Manufacturers' Secretary brought about a gradual but none-the-less good response.

In November, 1943 a facsimile of the cover of the brochure was developed and electros of this made available to advertisers.

Stickers were also designed similar to the electros for use on letterheads, programs, etc. Approximately 150,000 of these stickers were distributed, many of these by direct request.

Further Activities of the Field Director

During the months of October and November, 1943 the Field Director made an extended trip which covered the meetings of the

New York Section, A.W.W.A.—Binghamton, N. Y.
North Dakota Water and Sewage Conference—Grand Forks, N. D.

Kansas Municipal Utilities Assn.—Emporia, Kan.
Southwest Section, A.W.W.A.—Oklahoma City, Okla.
Des Moines, Iowa Engineers Club—Des Moines, Iowa.
Missouri Valley Section, A.W.W.A.—Des Moines, Iowa.
Wisconsin Section, A.W.W.A.—Milwaukee, Wisc.
Federation of Sewage Works Assn.—Chicago, Ill.
California Section, A.W.W.A.—Los Angeles, Calif.

A trip was made in the latter part of November to Fort Lauderdale, Florida and to Roanoke, Virginia, where the program was very well received by the members of the American Water Works Association.

In New York State tentative arrangements were made to utilize the services of the Area Coördinators of Mutual Aid, O.C.D. organization to further the program and the New York State Planning Commission recognized the need for water and sewage works in their program.

Very excellent use of the *Blueprint Now* slogan was made by the Manufacturers' Secretary by the use of signs at the Federation meeting and the A.W.W.A California Section meeting in October.

In November, contact calls were made by the Field Director in California, Washington, Oregon and Utah. A special luncheon was arranged in San Francisco for local engineers and officials who would be interested and postwar planning discussed. The possibility of California adopting a program of planning aid to cities, etc., as New York has was considered and data furnished. On June 20, 1944, the Governor of California signed a bill which made available to the local governments of California, $10,000,000 for postwar planning aid.

The States of Oregon and Washington have been greatly affected by government programs of electrification and also by the U. S. Reclamation Service acting as engineers to the cities in the construction of public water supplies. This is likewise true in Utah and California.

The water supply problems of the Northwest are not primary, but the sewage collection and disposal problem is of the first magnitude. Determined efforts were made to further the program of elimination of stream pollution but with the enormous dilution available in the streams and coastal waters, it may be considerable time in the future before the solution is effected.

The Conference of State Sanitary Engineers in October, 1943 by resolution virtually adopted the Committee program *in toto* and it is believed that the active coöperation of the State Sanitary Engineers aided greatly the work of the Committee.

At a meeting of the Committee held in New York in January, 1944 the negative attitude on federal aid for postwar water and sewage works construction was reaffirmed. This attitude was recorded with the Congress by letter dated February 25, 1944. Copies of the letter were also sent to the various trade publications.

There was also discussed to some extent at the Committee meeting in January the desirability of forming state committees. On February 4, 1944 a letter was addressed to each State Sanitary Engineer asking him to name those persons in his state whom he thought would serve upon a state postwar planning committee. Only 21 replies were received and of these 21 replies too few were really willing to coöperate to make the venture a worthwhile Committee activity. However, the names of such persons were added to the Committee mailing list for future publications.

The meetings attended by the Field Director for the month of January where talks were given included:

Colorado Society of Engineers at Denver, Col.
New York State Section, A.W.W.A.—New York, N. Y.
American Society of Civil Engineers—New York, N. Y.
Massachusetts Public Health Assn.—Boston, Mass.

During the first three weeks of February, 1944 the Field Director spent his time in Texas attending one meeting after another and consulting the mayors, city engineers, consulting engineers, water and sewage superintendents and other interested city officials. The postwar planning activities ranged from very active prosecution, as at Houston, to no planning at all at McAllen where bond defaulting has resulted in an effort on the part of the city to pull itself out of the mire by buying the private water company. Personnel shortage was found everywhere with civil service pay schedules acting as a severe brake in cities such as Austin, where they do their own designing, etc. The need for intelligent management in the smaller cities is very evident especially in the sewage field and there is a similar need for men in the water works field. There is plenty of room for

advancement in both fields but how to educate and guide the operators and managers of tomorrow is a problem when we consider the wage scale offered to men in these positions. A few months later the voters of Wichita Falls, Tex., approved a $3,500,000 water supply project.

A number of stops were made by the Field Director in Arizona. Here, it is interesting to note that the United States-Mexico International Boundary Commission has arranged for the design of two sewage plants both in the United States to treat the sewage from both Mexican and U. S. cities at Nogales and Douglas with the Mexican cities paying a portion of the cost of treatment. Work at Phoenix will constitute the largest water and sewage work in the state. The State Sanitary Engineer sent to each city and to the consulting engineers a list of recommended improvements throughout the state.

The Field Director's trip was continued through Tennessee, Alabama and Georgia and South Carolina. Work in South Carolina will be little but interest is growing in better sanitation since the growth rate of the state has not been conducive to large construction projects relating to water supply and sewage treatment.

During the month of March, 1944, Governor Kelly of Michigan signed a bill which appropriates $3,000,000, as an aid to the cities in planning. Field contacts with the State Planning Board and the State Department of Health and Stream Control Commission may have had a salutary effect.

Conferences at Richmond, Virginia, disclosed the fact that cities can under a 1944 bill accumulate funds for postwar construction.

During the months of April and May another trip was undertaken by the Field Director. This trip covered 9,500 miles. This trip covered calls in Michigan, Illinois, Indiana, Ontario, Missouri, Ohio, Pennsylvania, Minnesota, New York, Kentucky, Tennessee, North Dakota, Montana and Washington. At one meeting in Washington, Governor Langley gave a very fine talk on postwar planning, stressing the need for preparation of plans and specifications. Contact was established with the newly appointed executive secretary of the Washington Stream Pollution Control Commission.

New Jersey was the third state to offer state financial and to municipalities, etc., in designing postwar improvements. A fund of $500,-

000.00 was set up for expenditure after July 1st to pay one-half of the cost of design of improvements but not to exceed $50,000 to any one political subdivision of the state.

During the month of June, 1944 the Field Director addressed the meetings of the Municipal Finance Officers Association, the American Water Works Association and gave informal talks before the Ohio Conference on Sewage Treatment and the Central States Sewage Works Association.

Over a period of ten months, the subject of *Blueprint Now* was presented before 23 water works meetings serving 38 states, before 8 sewerage groups representing 11 states and before 5 water and sewerage associations representing 6 states. The topic was also presented to 11 engineering societies, public health groups, etc. The health departments in 37 states and 15 state planning groups were personally visited as were city officials in 57 cities. In the 10 months, nearly 50,000 miles were travelled.

When Mr. Filby returned to Kansas City to resume his activities as a member of the firm of Black & Veatch on July 1st, 1944, the Committee expressed its appreciation of the services that he had rendered in the water and sewage works field over the country. Those services can never be precisely estimated but no one who has observed the ebb and flow in the sea of planning movements can reach any conclusion other than that Mr. Filby's work as Field Director was highly valuable.

On May 17, 1944 a request was received from the F. W. Dodge Corporation for permission to use, and promote the use of the Committee slogan and label and to apply it to all construction. After a discussion in the Committee meeting of June 15th, permission was granted. The F. W. Dodge Corporation has already embarked upon a large promotional scale and due credit has been given to the Committee and to the Field Director who originated the slogan. The F. W. Dodge Corporation is the publisher of such reports as the Dodge Reports, Sweets Files, Architectural Record, Home Owners Catalogues, etc. Permission has been granted to them to order directly from the printer and/or engraver stickers and electros, provided no profit is made on the transactions.

FINANCES

From July, 1943 through November, 1944 the Committee expended the *net* total amount of $15,391.60. Committee expenditures may be broken down as follows:

Field Director's salary	$ 5,000.00
Field Director's expenses	4,826.20
Lettershop and steno	2,634.19
Promotional material	3,869.46
Office expense, stationery, telephone and telegraph	982.67
Miscellaneous	513.16
Total disbursements	17,825.68
Receipts	2,434.08
Net disbursements	$15,391.60

Of the original amount budgeted by the four associations cooperating in the Committee's support $2,608.40 remains unexpended. As of November 30, 1944 the balance of all original dollar commitments of the New England Water Works Association, the Federation of Sewage Works Associations and the American Water Works Association will be turned over to the Secretary of the Water and Sewage Works Manufacturers Association for his handling. Periodic accounting for funds derived from the constituent associations will be continued until such time as no monies remain except those that derive from the Water and Sewage Works Manufacturers.

At the present time and for the duration of the life of the Committee, if conditions permit, source material for the bulletin, *Blueprint Now in Action,* will clear across the desk of the Secretary of the Committee. He will maintain contact with the Industrial Advertising Division of the Johns-Manville Company, Mr. Howard Bain in particular who has been preparing and is expected to continue to prepare the format of each issue of the bulletin. Final copy of the bulletin will be cleared by the Secretary of the Committee and then turned over to the office of the Secretary of the Water and Sewage Works Manufacturers Association. All details relating to the production of the bulletin by the printer, mailing, etc., will be handled by that office.

HARRY E. JORDAN
Secretary

SCHUYLKILL WATER WORKS, PHILADELPHIA, PA. 1840.
From an engraving by J. C. Armytage based on a drawing by W. H. Bartlett.